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PROCEEDINGS

OF THE

Forty-Fifth Annual Meeting

Indiana Academy of Science

VOLUME 39

1929

STANLEY A. CAIN, Editor

Held at Earlham College
Richmond, Indiana
December 5-7, 1929.

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1930

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OFFICERS AND COMMITTEES FOR 1929

President, Louis J. Rettger, Indiana State Normal, Terre Haute.
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*Deceased. †Officers continued—Annual meeting not held because of influenza epidemic. ‡Listed in year of Proceedings edited.

MINUTES OF THE SPRING MEETING

POKAGON STATE PARK, LAKE JAMES, INDIANA.

The Indiana Academy of Science met for its regular spring meeting at Lake James, May 23-25, 1929. A business session was called to order at 7:30 p. m., May 23, in Potawatomie Inn. Chairman Friesner reported for the committee on date of winter meeting. Action was taken setting the date for the winter meetings on December 7-9, 1929. Chairman Markle explained the program plans for the following day. Mr. Lyell Shank of Steuben County, author of the bill which established the Lake James site as Pokagon State Park, gave an address on physiographic features of the county. Dr. Stolz discussed the historical aspects of the region with special reference to a boundary dispute regarding the northern boundary of the State involving the present site of Pokagon State Park. The formal program then gave way to a period of social intercourse for the remainder of the evening.

Friday was spent in visiting numerous lakes and bogs under the leadership of Dr. Weatherwax.

A banquet was enjoyed by 110 members of the Academy in Potawatomie Inn on Friday evening. Following the banquet the following items of business were transacted: President Rettger appointed Mr. John S. Wright, Mr. Frank C. Evans, and the Secretary a committee to report at the next meeting of the Academy regarding proposed legislation concerning tariff on scientific instruments. Mr. W. A. Cogshall, Mr. Barnard Schockel, and Mr. W. E. Eddington were appointed a committee to present to the Academy at its next meeting a report concerning the proposed change in the calendar. Chairman Enders reported 12 names of applicants for membership in the Academy. All applicants were elected to membership by unanimous vote of the Academy. Their names will be found in the membership list with "S" following the date of their election to membership.

Colonel Richard Lieber addressed the Academy on the work of the State Conservation Department. Mr. Taylor addressed the Academy concerning the glacial geology of the region. Brief addresses were given by Dean Coulter, Dr. A. W. Butler, and Dr. Blatchley. President Rettger appointed Dr. A. J. Bigney, Dr. H. A. Zinsser, Dr. D. M. Mottier, Dr. F. C. Payne, Dr. H. E. Enders to represent the Academy at the meeting of the National Conference on State Parks held at Clifty Falls on May 7-9, 1929.

RAY C. FRIESNER, Secretary.

WINTER MEETING

Program of the Forty-fifth Annual Meeting of

THE INDIANA ACADEMY OF SCIENCE

held at

EARLHAM COLLEGE

RICHMOND, INDIANA

December 5-7, 1929

Thursday, December 5, 1929

10:00 a. m. Meeting of Entomologists, Carpenter Hall.

12:30 p. m. Lunch for Entomologists in College Dining-Room.

7:00 p. m. Meeting of Executive Committee.

8:15 p. m. Address on Man and Nature in the Batak Lands of Sumatra, by Dr. H. H. Bartlett, Chairman of the Department of Botany at the University of Michigan.

Friday, December 6, 1929

8:00-8:30 a. m. Registration, Faculty Room in Carpenter Hall, Earlham College.

8:30 a. m. Business Session, Auditorium, Carpenter Hall.

9:00 a. m. General Program, Auditorium, Carpenter Hall.
Address of Welcome, President William Cullen Dennis, of Earlham College.

In Memoriam—

George A. Albertson, by J. A. Nieuwland
Andrew J. Bigney, by Charles E. Torbet
John M. Coulter, by Henry C. Cowles
John C. Dean, by Russell Sullivan
John S. Kingsley, by Fernandus Payne
Robert Ridgway, by Amos W. Butler

The Charles R. Dryer Memorial in Pokagon State Park. Fred J. Breeze, Ball Teachers College.

Termites, Parasol Ants and Sloths of a Tropical Jungle. H. E. Enders, Purdue University.

The State Park Problem. Stanley Coulter, Indianapolis.

History and Results of Nature Guiding in Indiana State Parks. Sidney Esten, Indianapolis.

10:00 a. m. Sectional Meetings.

1:30 p. m. Sectional Meetings Resumed.

3:30-5:00 p. m. Tea to Members of the Academy by The Faculty of Earlham College.

6:30 p. m. Academy Dinner.

8:00 p. m. Brief Business Session.
Address of the Retiring President—The Outlook in Physiology.
Louis J. Rettger, Indiana State Normal, Terre Haute.

MEETINGS OF SECTIONS

BOTANY (Room 221, Carpenter Hall)

STANLEY A. CAIN, BUTLER UNIVERSITY, Chairman

1. Chromosome Numbers in the Oaks. Ray C. Friesner, Butler University. (To be published in the Butler University Botanical Studies, No. 7, Jan. 1930.)
2. A Note on the Hybridizing of Freesias. W. P. Morgan, Indiana Central College.
3. Notes on the Structure of Some Carboniferous Plants. J. Hobart Hoskins, University of Cincinnati.*
4. Morphology and Development of the Flower of Soybean. A. T. Guard, Purdue University.*
5. Algae of Monroe County, Indiana III. F. M. Andrews, Indiana University.
6. Studies in Pollen V. F. M. Andrews, Indiana University.
7. A Pressure Cell. F. M. Andrews, Indiana University.
8. Observations of the Dwarf Mistletoe, *Arceuthobium pusillum.* T. G. Yuncker, DePauw University.
9. Forest and Prairie, Benton County, Indiana. Winona H. Welch, Indiana University.
10. A Wild Flower Sanctuary on the Tippecanoe. Fred J. Breeze, Ball Teachers College.
11. Indiana Fungi, XII. J. M. Van Hook, Indiana University.
12. The Action of Environment in the Development of Ectotrophic Mycorrhizas. K. D. Doak, Purdue University.†
13. Indiana Plant Diseases, 1928. W. W. Gardner and E. B. Mains, Purdue University.
14. Scab of Small Grains and Feeding Trouble in Indiana in 1928. E. B. Mains, C. M. Vestal and E. B. Curtis, Purdue University.
15. Staling Phenomena in Fungi. C. L. Porter, Purdue University.*
16. Some Ecological Factors Inhibiting Herb Developments Under Hemlock: Turkey Run. Rexford F. Daubenmire, Butler University. (Published in Butler University Botanical Studies, No. 6, January 1930.)
17. Mineral Requirements of Deciduous Trees: I. Quercus. K. D. Doak, Purdue University.†
18. Subalpine Vegetation of the Smoky Mountains. Stanley A. Cain, Butler University. (To be published in the Botanical Gazette, 1930, under the title "Hydrogen-ion Concentration and Plant Distribution in the Great Smoky Mountain National Park, Tennessee.")
19. The Hydrogen-ion Reactions of the Soils of Indiana Ferns. Joe R. Craw. Butler University.

*Not published in this volume.
†Work in progress—to be published later.

20. Floristic and Hydrogen-ion Studies of a River Bluff. Stanley A. Cain and Ray C. Friesner, Butler University. (To be published in the Butler Botanical Studies, No. 10 & 11, March, 1930.)
21. Evaporation Studies in the Sycamore Creek Region. Stanley A. Cain and Ray C. Friesner, Butler University. (To be published in the Butler University Botanical Studies, No. 9, March, 1930.)
22. Pteridophytes of Turkey Run State Park. Frederick H. Test, Purdue University.
23. Germination and Regeneration Studies in Certain Species of Oaks. Ray C. Friesner, Butler University. (To be published in Butler University Botanical Studies, No. 12, April, 1930.)
24. A Simple Respirometer for Quantitative Class Experiments. Raymond E. Girton, Purdue University.
25. Plants New or Rare in Indiana, XV. Chas. C. Deam, Bluffton.
26. List of Flowering Plants and Ferns in the Dunes State Park, Porter County, Indiana, Supplement. M. W. Lyon, Jr., South Bend. (Published in the American Midland Naturalist, March, 1930.)
27. Notes on Teaching and Microtechnical Devices Used in Biology. M. S. Markle, Earlham College.*
28. The Ecology of Turkey Run State Park. Part II., The Canyons: Part III., The Uplands. Caroline H. Swanson, Crane Technical High School, Chicago.*
29. Culture Methods Used in Mycorrhiza Investigations. K. D. Doak, Purdue University.†
30. Enumeration of the Vascular Flora of a Limestone Area of the Bloomington Quadrangle, Monroe County, Indiana. Gladys Price and Winona H. Welch, Indiana University.
31. Some Flowering Plants Collected in Parke County, Indiana. Rexford F. Daubenmire, Butler University.
32. New Parasitic Fungi of Montgomery County, Indiana. H. J. Lee, Wabash College.

CHEMISTRY AND BACTERIOLOGY

(Lecture-room, Chemical Laboratory, Parry Hall)

E. G. MAHIN, NOTRE DAME, Chairman.

1. The Decomposition of Cellulose in Nature. P. A. Tetrault, Purdue University.
2. Homologous and Hetrologous Antibody Production. C. A. Behrens, Purdue University. (To be published in the Journal of Bacteriology, 1931.)
3. A Comparison of Halogeno and Oxyacids. J. A. Nieuwland and T. H. Vaughn, Notre Dame.
4. Modifying Influence of Ferrosilicon upon Gas Carburization. E. G. Mahin and J. S. Dougherty, Notre Dame.*
5. Effect of Moisture Content upon Cementation by Mixed Carburizers. E. G. Mahin and C. E. McDermott, Notre Dame.*
6. Silicon Carburizers for Low-carbon Steels. E. G. Mahin and C. Atchinson, Notre Dame.*
7. Stability of Barium Sulphate at High Temperatures. E. G. Mahin and Brother Kilian, C. S. C., Notre Dame.
8. Pond Water Composition and Mosquitoes. R. H. Carr, Purdue University.

*Not published in this volume.
†Work in progress—to be published later.

9. Concerning Certain Pyridene Homologs. J. W. H. Aldred with R. E. Lyons, Indiana University.
10. Organic Compounds of Selenium, I. and II. W. E. Bradt and M. Van Valkenburgh, University of Cincinnati.

GEOLOGY AND GEOGRAPHY
(Room 112, Carpenter Hall)

E. R. CUMINGS, INDIANA UNIVERSITY, Chairman.

1. Two Fort Wayne Wells in the Silurian and their Bearing on the Niagaran of the Michigan Basin. E. R. Cumings, Indiana University.
2. Silurian Reefs Near Tiffin, Carey and Marseilles, Ohio. E. R. Cumings, Indiana University.
3. Lists of Species from the New Corydon, Kokomo and Kenneth Formations of Indiana, and from Reefs in the Mississinewa and Liston Creek Formation. E. R. Cumings, Indiana University.
4. Occurrence of Fissures in Clay, Coal and Stone. George W. Finley, Brazil, Indiana.*
5. Intraformational Solution of the Floyds Knob Limestone. Paris B. Stockdale, Ohio State University.
6. Notes on Some Northwestern Indiana Rock Exposures. Robert R. Schrock and Clyde A. Malott, Indiana University.
7. Aerial Photographs of Jennings County. T. M. Bushnell, Purdue University.
8. Pictorial Relief Map of Indiana. H. B. Schockel, Indiana State Teachers College. (To be published in Teachers College Journal, 1930.)
9. Geography of the Indiana Oolitic Limestone Industry. Stephen S. Visher, Indiana University. (To be published in Economic Geography, 1931.)
10. Land Utilization in the Bloomington Area. J. E. Switzer, Indiana University.†
11. A Simple Device for Measuring Relative Humidity. Fred J. Breeze, Ball Teachers College.*
12. Introductory Geography. B. H. Schockel. State Teachers College. (To be published in the Journal of Geography, 1930.)
13. Some Notes on the Fort Apache Region, Arizona. Albert B. Reagan, Ouray, Utah.*
14. Causes of Earthquakes and Glaciation. Tunis J. Quick, San Antonio, Texas.*
15. The Relation of Geologic Structures in Indiana to the Isomagnetic Lines of Vertical Intensity and to the Anomalies of Magnetic Intensity. W. N. Logan, Indiana University.
16. Notes on Unearthing Parts of a Mastodon Skeleton. Edward Kintner, Manchester College.

PHYSICS, ASTRONOMY, MATHEMATICS
(Physics Laboratory, basement of Carpenter Hall)

J. E. SMITH, FRANKLIN COLLEGE, Chairman.

1. The Product of Two Integrals. Will E. Edington, Purdue University.
2. Astronomical Interpretations of a Formula in the Theory of Integral Invariants. Oliver E. Glenn, Lansdowne, Pa.

*Not published in this volume.
†Work in progress—to be published later.

3. Photography of the 1929 Eclipse with a New Type Reflector. W. A. Cogshall, Indiana University.
4. Ionization and Thermal E. M. F. in Selenium Vapor. W. T. Sproull and R. E. Martin, Hanover College.
5. Low Voltage Hazards. Arthur L. Foley, Indiana University. (Not to be published.)
6. Electrical Conductivity of the Atmosphere at Terre Haute, Indiana. J. F. Mackell and Ira Vance, Indiana State Normal.
7. A Student Grating Spectrometer. Edwin Morrison, Michigan State Agricultural College.*
8. Some Mistaken Ideas Concerning Sound Absorbers. Arthur L. Foley, Indiana University.
9. A New, Efficient, and Economical Type of Sound Absorbing Material, and a Simple and Inexpensive Method of Installation. Arthur L. Foley, Indiana University.
10. Output Charactersitics of Magnetic Pickups. J. B. Hershman, State Teachers College.
11. Resistance of Radio Condensers. R. R. Ramsey, Indiana University.
12. Selective Transmissivity of Various Kinds of Glass. J. F. Mackell and Wm. S. Hart, State Teachers College.†
13. High Frequency Rays in the Aurora Borealis and High Altitude Tests on Mt. Everest. Elmer A. Smith, Secaucus, N. J.

ZOOLOGY (Room 321, Carpenter Hall)

B. H. GRAVE, DEPAUW, Chairman.

1. Insects of Indiana for 1929. J. J. Davis, Purdue University.
2. The Fish Tapeworm and its Occurrence in Indiana: Report of a Fourth Specimen. M. W. Lyon, Jr., South Bend. (To be published in the Journal of The Indiana Medical Association, Feb. 1930.)
3. The Digestion of a Mouse by a Tarantula. John S. Andrews, Purdue University.
4. Some Structural Peculiarities of *Stenobothrium macrobothrium*, Oiesing. Francis J. Wenninger, University of Notre Dame.
5. Cytoplasmic Structures in a Developing Insect Egg. Fernandus Payne, Indiana University.†
6. Behavior of the Larva of *Bugula flabellata*. B. H. Grave, DePauw University. (To be published in the Journal of Morphology and Physiology, 1930.)
7. Lunar Periodicity in Spawning. B. H. Grave, DePauw University. (To be published in Biological Bulletin, 1930.)
8. A Summary of the Distribution of the Different Types of Sense Organs in the Termite, *Termopsis angusticollis*. Bessie Noyes, State Teachers College.*
9. Commercial Use of Baits for the Control of Oriental Fruit Worm. R. C. Simpson, Vincennes.†
10. Migration of Four Species of Snails into the Tippecanoe River System. Herman P. Wright, Indiana University.†
11. The Relation of the Vertical Distribution of the "Cisco" to the Distribution of Dissolved Oxygen. Will Scott, Indiana University. (To be published in Bul. 2, Dept. Conservation, Div. Fish & Game, 1930.)

*Not published in this volume.
†Work in progress—to be published later.

12. Records of Indiana Dragonflies, IV., 1929. Elwood Montgomery, Purdue University.
13. Ontography as the Science of Biography. Robert Hessler, Indianapolis.*

MINUTES OF THE EXECUTIVE COMMITTEE

The Executive Committee was called to order at 7:00 p. m., December 5, 1929. The following members were present: F. M. Andrews, C. A. Behrens, Wm. M. Blanchard, H. L. Bruner, A. W. Butler, W. A. Cogshall, Stanley Coulter, E. R. Cumings, J. J. Davis, C. C. Deam, H. E. Enders, A. L. Foley, R. C. Friesner, M. W. Lyon, E. G. Mahin, W. J. Moenkhaus, W. P. Morgan, D. M. Mottier, F. B. Wade, J. S. Wright.

Reports of officers followed:

Academy Foundation—Chairman Butler presented the following report:

December 1, 1928, balance on hand	$ 103.34
Total receipts, interest and other additions	431.12
Total	$ 534.46
Investments made during the year	500.00
Balance on hand December 1, 1929	34.46

ASSETS

U. S. 4th L. L. Bond	$ 50.00
Muncie Masonic Temple, Preferred	200.00
Railroadmens Bldg. and Sav. Assoc., 21 shares	2,200.00
Balance as shown above	34.46
Total Assets	$2,484.46

Archaeological Survey—Chairman Logan reported that 152 archaeological specimens were added to the museum collection during the year, making a total of 4,676 now in the museum. He reported the excavation of mammoth remains in Jackson County and the marking of several supposed burial grounds which will be investigated in the future.

Auditing Committee—Chairman Edington reported that the books of both Editor and Treasurer had been audited and found to be correct.

Biological Survey—In the absence of Chairman Dietz no report was made. Dr. Davis suggested that a tabulation of the questionnaire on Biological Survey be made and published in the Proceedings. Upon motion this was referred to the Editor to be done.†

Tabular Presentation of 1929 Biological Survey Questionnaire [1], [2], [3]

*Not published in this volume.

†**"A more complete and revised summarization of the questionnaires will be presented next year by the Biological Survey Committee. The editor is responsible for the present condition of the report."**

[1]The questionnaire was prepared and sent out by Chairman H. F. Dietz towards the end of 1928. At the Richmond meeting (1929) it was voted that the data from the questionnaires be assembled for publication by S. A. Cain, incoming editor.

[2]The symbols following the names of the various Academy members have the following meaning: (B) they maintain a bibliography of papers on the special field listed; (These bibliographies, in part, are in the hands of the editor, also lists of original publications by members applying to Indiana Biological Survey. It is planned to publish a Bibliography on Indiana Biology at a near date); (C) they maintain a collection, open for inspection; (P) they have published on the subject.

[3]Addresses will be found in the membership list at the end of this volume.

CONSERVATION

LIEBER, RICHARD; COULTER, STANLEY

POPULAR SCIENCE WRITING

CAIN, S. A., DAVIS, J. J., DIETZ, H. F., KIPLINGER, W. C., EDINGTON, W.

BOTANY

STATE FLORA, Coulter, Stanley, (P); Deam, Chas. C. (B. C. P.)

COUNTY FLORAE

Jasper County, Welch, W. H. (B. C. P.).

Lawrence County, Wible, P. G. (C).

Marion County, Cain, S. A. (C. P.); Friesner, R. C. (C); Philips, Alice (C. P.); Potzger, J. E. (C).

Monroe County, Andrews, F. M. (C. P.); Price, Gladys (C. P.); Welch, W. H. (C. P.).

Montgomery County, Bechtel, A. R. (C).

Morgan County, Cain, S. A. (C. P.); Friesner, R. C. (C. P.); Potzger, J. E. (C).

Parke County, Daubenmire, R. F. (B. C. P.); Esten, S. R. (B. C. P.); Swanson, C. H. (B. C. P.); Test, Fred, Jr., (C. P.).

Porter County, Lyon, Jr., M. W. (B. C. P.).

TAXONOMY AND DISTRIBUTION OF SPECIAL GROUPS

Phycology (algae) Andrews, F. M. (B. C. P.); Palmer, C. M. (B. C. P.).

General Mycology, Arthur, J. C. (B. C. P.); Lockwood, L. B. (C. P.).

Uredinales, Arthur, J. C. (B. C. P.).

Fungi Imperfecti, Lockwood, L. B. (C).

Polyporaceae, Swanson, C. H. (C. P.).

Lichens, Hufford, G. N. (C).

Bryophyta, Pickett, F. L. (B. C. P.); Swanson, C. H. (B. C. P.); Yuncker, T. G. (C. P.).

Pteridophyta, Friesner, R. C. (B. C. P.); Greene, F. C. (P); Test, Fred, Jr., (C. P.).

Graminiae, Cummings, M. P. (B. C. P.); Deam, Chas. C. (B. C. P.); Hansen, A. A. (B. C. P.); Riecken, W. E. (B. C. P.); Weatherwax, Paul (B. C. P.).

Cyperaceae, Hass, F. A.

Trillium, Friesner, R. C. (B. C. P.).

Taxodium, Cooprider, J. L. (B. C.).

Ericales, Cain, S. A. (C).

Cuscuta, Yuncker, T. G. (B. C. P.).

Arceuthobium, Yuncker, T. G. (B. C. P.).

Compositae, Amidei, T. P. (C); Friesner, R. C. (C).

Plankton, Hinman, J. J. (B. P.).

Weeds, Hansen, A. A. (B. C. P.).

Trees & Shrubs, Deam, Chas. C. (B. C. P.).

HORTICULTURE, Brown, H. D. (P); Douglass, B. W. (P).

PATHOLOGY, Cooper, D. C. (P); Gardner, N. W. (B. P.); Leer, W. E. (P); Ludwig, C. A. (P); Orton, C. R. (P).

ECOLOGY

Blaydes, G. W.

Cain, S. A. (General ecology of Bacon's Swamp, Marion County, an extinct glacial lake) (Ecology of secondary successions in upland hardwood, Morgan County).

Cooprider, J. L. (Ecology of Taxodium in Lower Wabash Valley).

Cowles, H. C. (Ecology of sand dunes of Lake Michigan and plant succession in vicinity of Chicago).

Daubenmire, R. F. (Tufa Deposits at Clifty Falls) (Ecology of Hemlock and Beech-Maple consociations at Turkey Run).

Emerson, F. W. (Underground organs of Bog Plants).

Friesner, R. C. (Ecology of secondary successions in upland hardwood, Morgan County).

McAvyo, Bernice

Philips, Alice (Biological Spectrum of Bacon's Swamp, Marion County).

Potzger, J. E. (Ecology of a river bluff, Morgan County).

Swanson, C. H. (Ecology of Turkey Run).

Welch, W. H. (Ecology of Fountain Park) (Ecology of limestone area in Bloomington Quadrangle) (Ecology of prairie woodlands, Benton Co.).

BACTERIOLOGY

RELATION TO PUBLIC HEALTH (Medicine, Biologicals, etc.) Adams, C. F. (B. P.); Burrage, S. (P); Carter, E. B. (C); Hinman, J. J. (B. P.); Miller, F. A.; Otten, R. E. (P); Richter, A. B.

ZOOLOGY

SPECIAL GROUPS

CESTODA, Wenninger, F. (B. C. P.).

NEMATODA, Zebrowski, G. (B. C. P.).

ANNELIDA, Lahr, J. P. (B. P.).

MOLLUSCA, Wright, H. P. (B. C. P.) (especially PLEUROCERIDAE & SPHAERIIDAE).

CRUSTACEA, Scott, W. (B. C. P.).

ARACHNIDA, Nester, H. G. (B. C. P.) (especially CHERNETIDIA of PSEUDOSCORPIONIDA); Zebrowski, G. (B. C. P.) (especially ACARINA).

ECONOMIC ENTOMOLOGY, Benton, C. (B. C.); Cartwright, W. B.; Davis, J. J. (B. C. P.); Dietz, H. F. (B. C. P.); Douglass, B. W. (P); Packard, C. M.

ODONATA, Kennedy, C. H. (B. P.); Montgomery, B. E. (B. C. P.); Williamson, E. B. (B. C. P.).

ISOPTERA (Termites) Dietz, H. F. (B. C. P.).

ORTHOPTERA, Pearson, N. E. (especially AMBLYCORYPHA of LOCUSTIDAE).

HEMIPTERA-HOMOPTERA, McAtee, W. L. (B. C. P.); Dietz, H. F. (P); and Mossison, H. (B. C. P.) (especially COCCIDAE); Benton, C. (B. C.) and Davis, J. J. (B. C. P.) (especially APHIDIDAE).

DIPTERA, Adams, C. F. (B. C. P.) (especially MYCETOPHILIDAE); Aldrich, J. M. (B. C. P.); Benton, C. (B. C.).

COLEOPTERA, Weber, R. G. (B. C.); Montgomery, B. E. (B. C. P.) (especially HALIPLIDAE); Davis, J. J. (B. C. P.) (especially SCARABAEIDAE).

HYMENOPTERA, Kinsey, A. C. (B. C. P.) (especially CYNIPIDAE).

CRASPEDACUSTA, Payne, F. (P).

PISCES, Belcher, C. J. (B. C.); Jordon, O. S. (B. C. P.); Myers, G. S. (B).
AMPHIBIA, Esten, S. R. (B. C. P.); McAtree, W. L. (P); Myers, G. D. (B. P.); Springer, S. (B. C. P.); Tasker, R. C.
REPTILIA, Esten, S. R. (B. C. P.); McAtree, W. L. (P); Myers, G. D. (B. P.); Springer, S. (B. C. P.); Tasker, R. C.
AVES, Butler, A. W. (B. C. P.); Esten, S. R. (B. C. P.); Fischer, M. L. (P); Krause, H. (C. P.); McAtree, W. L. (B. C. P.); Perkins, S. E. (P); Ridgway, R. (B. C. P.); (Deceased); Zimmerman, H. A.
MAMMALIA, Butler, A. W. (B. P.); Esten, S. R. (B. C. P.); Lyon, M. W. (C. P.); McAtree, W. L. (P).

PALEONTOLOGY

NATURAL GROUPS

GENERAL INVERTEBRATES, Guernsey, E. V. (B. C. P.).
BRYOZOA, Cummings, E. R. (B. C. P.).
BRACHIOPODA, Cummings, E. R. (B. C. P.)

GEOLOGICAL GROUPS

ORDOVICIAN, Campbell, G. (C).
SILURIAN, Campbell, G. (C); Cummings, E. R. (B. C. P.).
DEVONIAN, Campbell, G. (C).
PENNSYLVANIAN, Hoskins, J. H. (B. C. P.).
NIAGARAN, Cummings, E. R. (P).

Editor—Editor Davis reported as follows:

Volume 38 of the Proceedings was distributed September 4. The size of the volume was somewhat smaller than the year before in order to come within the imit of the state appropriation.

The financial report, not including clerical help and other editorial expenses, as follows:

STATE FUNDS

Annual appropriation for 1928 Proceedings		$1,500.00
Cost of 1928 Proceedings	$1,561.13	
Balance due, paid from reprint fund		61.13
Total		$1,561.13

REPRINT ACCOUNT

Balance from 1928 account		$ 0.00
Received from authors for reprints		277.89
Interest on savings account		3.19
Total		$ 281.08
Wm. B. Burford for extra reprints	$ 71.00	
Wm. B. Burford for extra cost of Proceedings	61.13	
Express, postage, etc., on reprints not chargeable elsewhere	5.90	
	$ 138.03	$ 138.03
Balance in Purdue State Bank		$ 143.05
Due from authors for reprints		7.60
Total		$ 150.65

EDITOR'S CODE[1]

1. Papers by members referring to the resources of Indiana, or of special interest to residents of the State, or those which are direct contributions to the science of the State, will be given preference. This will not refer to papers on chemistry, physics and similar subjects which have a wider application.

2. Papers submitted to the editor at the Winter Meeting will have priority for publication in the Proceedings.

3. Authors should be concise and limit their papers to necessary printed matter, illustrations and tabular material. The President's address, papers of exceptional merit, floras of counties, lists of insects, and the like, are obvious exceptions.

4. As a rule, papers presented before the Academy should not be papers previously presented elsewhere and they should be available for publication in the Proceedings. However, if papers are read which are not intended for the forthcoming volume of the Proceedings, the editor should be advised as to where and when the paper will be published; or if the paper is a preliminary report of work in progress, if it will be submitted for publication at a later date.

Authors can help the editor and printer and conserve printing funds by adhering to the following suggestions in preparing their manuscripts:

5. Manuscripts should be typewritten first sheets and not carbon copies.

6. All manuscript copy should be on one side only of letter-size paper, double or triple-spaced, with ample margins.

7. References should be included as footnotes, except when they average four or more to the printed page, when they should be grouped at the end. When the citations are included as footnotes they should appear in the manuscript immediately after the place of their citation, set off by lines running across the page. They should be given consecutive arabic numbers. When included at the end of the paper, the citations should be refered to in the manuscript by arabic numbers in parentheses, which numbers are derived from the alphabetical sequence of the authors cited. All citations should be complete in the following style:

> Gardner, Max. W. Indiana Plant Diseases, 1927. Proc. Ind. Acad. Sci. **38**: 143-157, 1928.

8. Illustrations should tell a worthwhile story. The illustration should accompany the manuscript but unattached to any of the copy. A legend, completely describing and explaining the text figure should accompany it on a separate sheet of paper. These text figures, diagrams, photographs, etc., should be numbered consecutively and referred to in the text somewhere before the point of insertion, which should also be indicated on the manuscript. Photographs should be contrasty on glossy paper. Drawings are usually reproduced as zinc etchings and should be in black ink on white, hard-surfaced paper; as compact as the purpose will permit.

9. The title of the paper should be as brief as practicable; of greater importance, however, is that the title is expressive of the scope of the paper.

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[1]This "code" represents a shortened and somewhat modified form of the one published in separate by J. J. Davis and his Editorial Committee, April 15, 1924.

10. The name of the author together with his institution or city of residence should immediately follow the title.

11. Long quotations should be avoided. Quotations should be duly cited for reference.

12. The handling of special type, as italics, capitals and bold face, is usually left to the discretion of the editor for the sake of uniformity; however, the author's preference will be followed in such instances as warrant exception.

13. Technical marks and symbols should be very plain and if necessary explained for the information of the editor and printer.

14. Spell out numerals from one to nine when used in the text and higher numerals at the beginning of a sentence. Spell out per cent in the text. In reference to figures in a sentence place in parentheses, (fig. 1) with lower case "f," while if not a part of the sentence, capitalize. (Fig. 1)

15. Manuscripts should be ready for publication at the time of the Winter Program Meeting. The practice of presenting papers before they have been written is to be discouraged by giving priority for publication to those papers received at that time. Furthermore, **a "dead line" set at ten days after the meeting will automatically exclude a paper from publication except under unusual circumstances.**

16. Authors are expected to purchase the regular quantity of 100 reprints at minimum prices which are quoted each year. Additional reprints can be had by special arrangement with the editor. All orders for reprints are to be placed when the galley proof is returned.

STANLEY A. CAIN, Editor, 1929-30.

Membership Committee—Chairman Enders read the names of 40 candidates. These were accepted into membership. Their names together with others elected during the meetings will be found in the membership list in this volume.

Press Secretary—No Report.

Program Committee—Chairman Markle presented the program of papers and meetings for Thursday and Friday.

Relation of Academy to State—Chairman Wallace reported that the appropriation of $1,500.00 for the publication of the Proceedings of the Academy was continued and will be available.

Research Committee—Chairman Foley called attention to the fact that members have not coöperated with the committee in the matter of supplying names of individuals who might be interested in supplying funds toward establishing scholarships.

State Library Committee—No Report.

REPORT OF TREASURER, INDIANA ACADEMY OF SCIENCE FOR THE YEAR, 1929

RECEIPTS:

Balance on hand January 1, 1929	$654.93
Collected from members as dues and initiation fees	918.00
Received from American Association for Advancement of Science	107.00
Total	$1,679.93

DISBURSEMENTS:

Secretary's Office				
Clerical expenses	$ 16.10			
Stationery and printing (includes letterheads and envelopes for all officers)	45.65			
Postage (includes postage for mailing Proceedings)	112.00			
Miscellaneous	13.21	$186.96		
Treasurer's Office				
Clerical expenses	16.75			
Stationery and printing	26.25			
Postage	18.16			
Miscellaneous	4.41	65.57		
Editor's Office				
Miscellaneous expenses for 1927, 1928, and 1929 Proceedings	147.25			
Part printing of 1928 Proceedings	108.34	255.59		
Program Committee				
Clerical Expenses	10.50			
Stationery and printing	77.55			
Postage	78.22			
Miscellaneous	1.86	168.13		
Academy Foundation		307.00	983.25	
Balance in bank			696.68	1,679.93

Respectfully submitted,
M. W. LYON, JR., Treasurer.

Examined and found correct January 24, 1930.
FRANK W. HORAN,
Member, Auditing Committee.

New Business—President Rettger announced a promise of $5,000.00 to the Academy Research Endowment Fund upon condition that the Academy raise a similar amount. The following committee was appointed to work out a plan for raising this money: John S. Wright, M. W. Lyon, and Wm. B. Blanchard.

The Academy voted to go on record as favoring the report of the National Committee on Calendar Simplification.

H. E. Enders, Academy Representative on the Council of the American Association for Advancement of Sciences, was instructed to press with vigor the invitation of the Academy and the City of Indianapolis to the American Association to hold its meetings for 1933 in Indianapolis.

The desirablility of adding to our membership more men of business who are interested in the cause of science was discussed. Upon motion duly carried, a special membership committee was appointed to take charge of these efforts, W. M. Blanchard, chairman, John S. Wright, Stanley Coulter, M. W. Lyon, Jr., A. L. Foley.

The desirability of attempting to secure through the State Board of Public Instruction more desirable interpretation of the law regarding preparation of science teachers was discussed and referred for action to a special Committee, composed of L. J. Rettger, Chairman, A. L. Foley, R. H. Carr, W. M. Blanchard, and R. C. Friesner.

Mr. E. G. Hill extended to all members of the Academy an invitation to visit the Hill Rose Greenhouses.

Invitations for the next Winter Meetings of the Academy were received from Franklin College, Hanover College, and Purdue University, and an invitation for the Spring Meetings was received from the Department of Conservation for the Clark County State Forestry Preserve at Henryville. These were referred to the Program Committee for recommendation.

Dr. Lyon suggested that membership blanks be mailed to all members when preliminary notices of the meetings are sent out.

The Secretary was instructed to send messages of sympathy and greetings to Dr. David Starr Jordan, Dr. Harvey W. Wiley, and Dr. Charles Stoltz. Night-letter telegrams were sent at the close of the Session.

The meeting was then adjourned to hear an address by Professor H. H. Bartlett, Chairman of Department of Botany at the University of Michigan. Professor Bartlett presented a most enjoyable address on "Man and Nature in the Batak Lands of Sumatra."

MINUTES OF THE GENERAL SESSION

Minutes of the Executive Committee were read and approved.

Chairman Enders presented the names of 30 additional applicants for membership. These were accepted.

President Dennis of Earlham College gave the Address of Welcome to the Academy after which the regular program of papers followed.

At a brief business session following the annual Academy dinner the following business was transacted:

The Program Committee recommended that the next Winter Meetings of the Academy be held at Franklin College.

Dr. Butler announced an anonymous gift of $25.00 to the Endowment Fund.

A resolution was presented by Dr. Cumings on behalf of the geology section regarding topographic and aerial mapping. The text of this resolution follows:

Resolution in regard to topographic and aerial mapping in Indiana:

Resolved that the Indiana Academy of Science again endorses and urges the topographic mapping of the State in coöperation with the United States Geological Survey, in the manner that has been carried out in most of the surrounding States. The Academy also urges the furtherance of aerial mapping by the State.

It is further voted that this resolution be referred to the Committee on the Relation of the Academy to the State.

Adopted by the Academy by unanimous vote, December 6th, 1929.

This was referred to the Committee on Relation of Academy to State.

President Rettger on behalf of the Academy expressed appreciation to Earlham College for its hospitality during the meetings.

President Rettger welcomed and introduced 15 members and guests of the Academy from Ohio.

Chairman Andrews of the Committee on Nominations reported the following recommendations for Fellows and Honorary Fellows and New Officers:

For Fellows

C. M. Palmer, Butler University.
Paris Stockdale, Ohio State University.
Ralph Hufferd, DePauw University.

A. F. Mackell, Indiana State Normal (at Terre Haute).
B. E. Montgomery, Purdue University.

For Honorary Fellow

Harvey W. Wiley, 506 Mills Bldg., Washington, D. C.

For New Academy Officers

President, Rolla R. Ramsey, Indiana University.
Vice-President, M. S. Markle, Earlham College.
Secretary, Ray C. Friesner, Butler University.
Treasurer, M. W. Lyon, South Bend.
Editor, Stanley A. Cain, Butler University.
Press Secretary, W. E. Edington, Purdue University.

RAY C. FRIESNER, Secretary.

GEORGE WILLIAM ALBERTSON

KALAMAZOO, MICHIGAN. January 11, 1886.

SOUTH BEND, INDIANA. June 7, 1929.

The Reverend George William Albertson, former Dean of the College of Science at the University of Notre Dame, died suddenly June 7, at the University Infirmary, after an illness of but four days.

He was well known to many members of the Indiana Academy of Science, and his death came as a distinct shock to all his many friends for it ended an eminent career as an educator and lecturer.

He was born near Kalamazoo, Michigan, in 1886. He attended the parochial school there, and after completing his secondary school education, he entered the University of Michigan. After two years of study there, he continued at the University of Notre Dame, receiving there in 1914 the degree of Litt. B. He then began his work in the Seminary, finishing his theological studies in 1919, and was ordained to the Priesthood in that year. Later that same year, he went to the Catholic University in Washington, D. C., and began work in bacteriology and in 1921 received the degree, Doctor of Philosophy. He pursued graduate work at the University of Chicago during the summer sessions of 1920 and 1921, and was immediately after assigned to the College of Science at Notre Dame. He has acted as professor of Botany and Bacteriology there to the time of his death. The past two years saw him Acting Dean of the College.

The development of the system of graduate study was greatly aided by the Reverend Doctor. For four years he was secretary of the Committee on Graduate Studies at the University, and during his administration, that department has grown surprisingly.

Shortly after the Annual Commencement at Notre Dame, Dr. Albertson, feeling entirely exhausted after a year intensive work and study, entered the University Infirmary for a short rest and a thorough medical examination before continuing his duties, so heavy during the summer months. His genial disposition and his ready smile made him endeared to all who knew him, and his death is sincerely regretted.

R. G. SMITH, University of Notre Dame.

ANDREW JOHNSON BIGNEY

MOORES HILL, INDIANA. February 15, 1864.

EVANSVILLE, INDIANA. November 13, 1929.

Andrew Johnson Bigney was born on a farm near Moores Hill, Indiana, February 15, 1864. He was the fourth child of Lemuel Bigney and Sarah Van Doren, his father having come to Indiana from Novia Scotia, his mother from New Jersey. He died at Evansville, Indiana, November 13, 1929, after an illness of only thirty-six hours.

He attended the rural school as a child and at the age of sixteen entered the preparatory department of Moores Hill College. Continuing his studies in the College of Liberal Arts, he was graduated in 1888 with the degree of Bachelor of Arts. The quality of his work and the breadth of his interests are indicated by the fact that at graduation he was offered positions in the depart-

ments of the classical languages and of the natural sciences. So anxious were the heads of these departments, Dr. J. H. T. Main and Dr. Charles W. Hargitt, to obtain the services of a young man of such unusual promise that they secured his release from an engagement previously entered into to become the Superintendent of the Rising Sun public schools. After careful consideration Dr. Bigney decided in favor of science and was elected Professor of Natural Sciences to take the place of Dr. Hargitt who in the meantime had accepted a position at Syracuse University.

After teaching four years at Moores Hill College Dr. Bigney went in the autumn of 1892 to Johns Hopkins University where he pursued graduate studies for two years. In the second of these years he was an assistant in biology at that institution. In 1894 he resumed his work at Moores Hill College as Professor of Biology and Geology. This position he held until June, 1917. At that time Moores Hill College closed its doors at Moores Hill. During the two years intervening between this date and the re-opening of the College at Evansville, Indiana, Dr. Bigney was given leave of absence. The first of these years he spent as a graduate student in Zoology at Harvard University, the second as Assistant Professor of Physiology at Syracuse University. At the opening of Evansville College in Evansville in the autumn of 1919 he began his work there as Professor of Zoology, the position which he held at his death. During the summer of 1929 he taught botany at the University of Southern California.

In addition to the bachelor of arts degree Dr. Bigney held a master's degree granted by Moores Hill College in 1891 and the honorary degree of Doctor of Science granted by that institution in 1910. He was a fellow of the Indiana Academy of Science and a member of the American Association for the Advancement of Science, of the National Geographical Society, and of Sigma Xi. In 1916 he was president of the Indiana Academy of Science.

Such in rapid review are the outstanding facts in the life of Dr. Bigney. To any one familiar with the social history of Indiana during the last half century they would suggest what might be duplicated in the lives of hundreds of workers in the field of education. And yet they are totally inadequate to set forth the real Andrew J. Bigney—the man of keen intellectual curiosity, beloved teacher, trusted administrator, the ideal husband, citizen and friend.

Dr. Bigney's chief interest as a student was in Zoology. To this field of study he devoted his time in his periods of graduate study at Johns Hopkins and at Harvard. The summers of 1902, 1911, and 1918 he spent at the Marine Biological Laboratory at Woods Hole. He received careful training, however, in his undergraduate days in other sciences. At different times in his life he found it necessary to teach chemistry, physics, geology or botany along with his major subject. Such was his knowledge of the fundamental principles and facts of these sciences that no student ever went from his classroom with any other feeling than respect for the grasp of the subject shown by the teacher.

Undoubtedly one reason for Dr. Bigney's success as a teacher was a breadth of training and fullness of knowledge that made it possible for him to see his own special field in the light of related fields. For it was as a teacher that he has a claim to a high place among those who have served in the colleges of his native state. He could have excelled in the field of research, but his warm human sympathies, his grasp of essential principles, his understanding of the world of nature and his deep and reverent love for every manifestation of life made him pre-eminent as a teacher. The work of the classroom and the laboratory was never neglected, and his students responded with rare interest and enthusiasm.

From those who have gone on into the professions and into graduate study comes the universal testimony that the foundations laid under Dr. Bigney's instruction never had to be re-laid. Hundreds of young people who have not become specialists or scholars have lived richer lives because the eyes of their understanding of things of nature have been opened in his classroom.

The confidence reposed in Dr. Bigney by his associates in the faculty and by the Board of Trustees is shown by the administrative positions entrusted to him. In the catalog of Moores Hill College for 1888-89 his name appears in the faculty list as secretary. In 1895 he was made registrar and continued in this position until the removal of Moores Hill College to Evansville. In 1905 he was elected to the position of vice-president. During the year 1915-16 he was acting president and in the autumn of 1916, with the coming to the presidency of Dr. Alfred F. Hughes, he was made Dean. During these years of service Dr. Bigney acquired an intimate knowledge of the inner life of the College and became the adviser of students with reference to both academic and personal problems. College presidents and other officials took to him their administrative problems. For many years he sat with the Board of Trustees of Moores Hill College in all meetings. He was an ideal adviser of students, by his sympathy and tact winning their confidence and leading them to make wise decisions in hours of perplexity. So ungrudgingly did he give himself to the demands of classroom and office that friends wondered how he stood up under the strain of his work.

In view of these facts it will not be surprising that Dr. Bigney left very little in the way of published articles. His knowledge of Moores Hill College and its alumni led him frequently to write historical articles. These will be found scattered through alumni and college publications. His scientific interests are indicated by articles on biological and archeological subjects published in the *Proceedings of the Indiana Academy of Science.* The results of a special study made in the zoological laboratory at Harvard University were published in the Journal of Experimental Zoology (Vol. XXVII., No. 8).

The name of Andrew J. Bigney will always be associated with the one college which his life as a student, teacher and administrator so fully personifies. As was said of him by a former president at the time of his death: "His going takes from Evansville College the outstanding personality connected with its history across the last half century. His life has been builded into the institution." And yet the college was not the only institution enriched by his life.

In 1896 he married Miss Carrie Ewan, a graduate of Moores Hill College of the class of 1894. Few unions have been so ideal. Mrs. Bigney made their home a retreat from the cares of the day's work, and stood with him through the years of labor and discouragement when the College they loved was struggling for its very life.

His interest in the church was not a mere official interest. It was secondary to a profound conviction that his life had been drawn into fruitful channels through obedience to a divine call and that he could render no service to others quite equal to sharing with them the Christian experience. Such a spirit—devout, sane, wholesome, free from even the taint of fanaticism and yet positively Christian—is rare indeed. Probably in this aspect of his life is to be found the key to the understanding of his personality.

Indiana may have produced scientists know farther afield than Andrew J. Bigney. His was not a nature that craved renown. As a teacher who knew how to open the things of the natural world to the mind of youth and to arouse in their spirits feelings of wonder and realization of the supreme worth of service

rendered in a search for truth, few have been his equal. Upon this gift and upon the influence of his genuinely Christian spirit upon men and women young and old whose love he won and cherished rest his claim to a place among the sons of Indiana who should not be forgotten.

CHARLES E. TORBETT, Evansville, Indiana.

JOHN MERLE COULTER[1]

NINGPO, CHINA. November 20, 1851.

YONKERS, NEW YORK. December 23, 1928.

John Merle Coulter, who founded the *Botanical Gazette*, and who edited it for more than half a century, died December 23, 1928, at Yonkers, New York.

The Gazette in its infancy was a very unpretentious undertaking, consisting each month of a four-page leaflet, the first number of which was issued at Hanover, Indiana, in November, 1875. At first the new journal was known as the Botanical Bulletin, but from the second volume it has been known as the Botanical Gazette, the change of name being made out of regard for the previously existing Bulletin of the Torrey Botanical Club.

JOHN M. COULTER

For the first few years M. S. Coulter, now better known as Stanley Coulter, was coeditor with his brother. In 1883 Charles R. Barnes, then at Purdue University, and J. C. Arthur, then at Charles City, Iowa, became joint editors with Professor Coulter. At that time the journal was much enlarged, and was

[1]Reprinted from the Botanical Gazette **87**: 211-217. 1929.

organized into departments. For many years the Gazette was published by the editors, who bore all financial, as well as editorial responsibility for the journal. At first the subscription price was but $1.00 a year, and for several years there was no advertising matter, yet almost from the outset the journal paid its way. In the first twenty years of publication the home of the Gazette changed with the abode of one of the editors; at first it was issued from Hanover, Indiana, then from Crawfordsville, Indiana, and Bloomington, Indiana, the successive homes of Professor Coulter. From Bloomington it went to Madison, Wisconsin, at that time the residence of Professor Barnes.

In 1896 the Botanical Gazette was taken over by the University of Chicago Press, under whose auspices it has since been published. At the same time several prominent American botanists became associate editors, and the following year a group of foreign botanists was added to the list of associate editors. Commencing with 1900, Professor Arthur ceased to be coeditor with Coulter and Barnes, and his name was added to the list of associate editors. Thenceforward the main editorial responsibility rested with Professor Coulter and Professor Barnes, with the assistance of the other members of the botany staff at the University of Chicago. Upon the death of Professor Barnes in 1910, Professor Coulter once more assumed the chief editorial responsibility, and he continued in this capacity until 1926, when the main responsibility passed to the writer of this sketch. Even after the chief editorial burden was set aside, Professor Coulter continued to maintain a lively interest in the journal, contributing many reviews and performing various other editorial functions.

The growth of the Botanical Gazette in size and in the number of fields covered in its articles is a measure of the growth of botany in America since 1875. At first the contributions were mostly short taxonomic or floristic notes, without illustrations. Gradually the major contributions lengthened, were more profound in character, and often were illustrated. Morphology was early added to taxonomy as a field of interest, and later contributions appeared in physiology, ecology, mycology, pathology, genetics, and the other fields of modern botany. If Professor Coulter had no other monument than the Botanical Gazette, his place in the botanical roll of honor would forever be assured.

John Merle Coulter was born in Ningpo, China, November 20, 1851, the son of missionary parents. Upon the death of his father in 1853, his mother returned to America with the children, taking up residence at Hanover, Indiana, her father's home. His boyhood days were spent in southern Indiana, mostly at Hanover. He attended Hanover College, from which he was graduated in 1870 with the degree of Bachelor of Arts. His first teaching position was at a Presbyterian Academy at Logansport, Indiana, where he remained from the autumn of 1870 through the spring of 1872, not as a teacher of botany, but as a teacher of Latin.

In 1872 an event occurred which had a profound influence on Professor Coulter's subsequent career. He was given an opportunity to join the famous Hayden Survey of the Yellowstone, which occupied most of his attention for two years. His appointment was as assistant geologist, but while spending some weeks at Ogden, Utah, where the party was outfitting, he spent his time in collecting and studying the plants of the neighborhood. This came to the notice of Dr. Hayden, who needed a botanist, since the originally appointed botanist of the expedition had failed him. So the position was given to Mr. Coulter, who always regarded this incident as a veritable turning point in his life.

The degree of Master of Arts was conferred on the young botanist in 1873 by Hanover College, and from 1874 to 1879 he was Professor of Natural Sciences at that institution. It was during these years that he and his brother founded the Botanical Gazette. In 1879 he was called to the chair of Biology at Wabash College, where he remained until 1891. In 1882 he received the degree of Doctor of Philosophy at the University of Indiana, which called him to the botanical professorship and the presidency in 1891. In 1893 he went to the presidency of Lake Forest University. In 1896 he was called to the headship of the new Department of Botany at the University of Chicago, where he remained until his retirement in 1925. In the latter year he took up his residence at Yonkers, New York, the seat of the Boyce Thompson Institute for Plant Research, which he helped to organize, and of whose Board of Directors he was a member from the outset.

Professor Coulter was a charter member of the Botanical Society of America, and was twice its president. He was a long-time member of the American Association for the Advancement of Science and its president in 1919, a member of the National Academy of Sciences, and a member of many other scientific societies at home and abroad.

The early work of Professor Coulter was mostly in the field of taxonomy. This was natural enough, for in the seventies and eighties most American botany was in this field. When he went to Washington to work up his western collections, he chanced to meet Asa Gray, who took a great interest in the young Indiana botanist; from that time forth until the death of Gray in 1888, the friendship between the two was close and intimate. Coulter always attributed much of his success to the influence of Gray. The Hayden expedition naturally enough suggested the early attention of Mr. Coulter to the flora of the Rocky Mountains, and one of his earliest works was s synopsis of the flora of Colorado, published in 1874 in collaboration with T. C. Porter. Commencing with 1875, Professor Coulter contributed many articles to the Botanical Gazette, the first of which were mainly taxonomic. In 1885 there appeared his well known Manual of the Botany of the Rocky Mountain Region, and in 1909 was issued the Manual of Rocky Mountain Botany in collaboration with Aven Nelson. His Botany of Western Texas appeared as a contribution of the United States National Herbarium in 1891-1894.

In 1881 Professor Coulter issued, in collaboration with Charles R. Barnes, a Catalogue of the Phaenogamous and Vascular Cryptogamous Plants of Indiana. Alone or in collaboration Professor Coulter issued a number of taxonomic monographs, as his Revision of the North American Hypericaceae in 1886; Synopsis of the North American Pines (with J. N. Rose) in 1886; various works on the Umbelliferae from 1887 to 1909, especially Revision of North American Umbelliferae in 1888, Synopsis of Mexican and Central American Umbeliiferae in 1900, Monograph of North American Umbelliferae in 1900, and North American Umbelliferae in 1909, all four with J. N. Rose. In 1894 and 1896 were published works on Cacti. In 1890 was issued the sixth edition of Gray's Manual of Botany, under the editorship of Sereno Watson and John M. Coulter.

Early in his career Professor Coulter turned part of his attention to the developing field of morphology, and many outstanding articles and books represent his contribution in this line of endeavor. Perhaps his first contribution in this field was a study of the development of a dandelion flower, published in 1883. Following this was a paper in 1887 on the development of the Umbellifer fruit. But it was after coming to Chicago that his great contributions to morph-

ology were made, mostly in collaboration with Charles J. Chamberlain. The most noteworthy of these were the volumes on the Morphology of Spermatophytes, Morphology of Angiosperms, and Morphology of Gymnosperms, published respectively in 1901, 1903, and 1910. Other morphological contributions were issued in the form of papers on the Phylogeny of Angiosperms in 1903, the Embryogeny of *Zamia* (with C. J. Chamberlain) in 1903, Development of Morphological Conceptions in 1904, Gametophytes and Embryo of *Torreya taxifolia* (with W. J. G. Land) in 1905, Relation of Megaspores to Embryo Sacs in Angiosperms in 1908, Embryo Sac and Embryo of *Gnetum gnemon* in 1908, Evolutionary Tendencies among Gymnosperms in 1909, An American *Lepidostrobus* (with W. J. G. Land) in 1911, the Endosperm of Angiosperms in 1911, and the Origin of Monocotyledony (with W. J. G. Land) in 1914.

In the field of botanical textbooks Professor Coulter made rich contribution. In 1886 appeared a Handbook of Plant Dissection by Arthur, Barnes, and Coulter, often familiarly called a botany ABC. Plant Relations appeared in 1901, Plant Structures in 1904, Plant Studies in 1904, Textbook of Botany in 1906, and Elementary Studies in Botany in 1913. Professor Coulter wrote the morphological section of the more advanced Textbook of Botany, issued in 1910 in collaboration with Charles R. Barnes and Henry C. Cowles.

Professor Coulter contributed also to fields other than those just noted. In 1914 he issued a book on the Fundamentals of Plant Breeding, and a book on the Evolution of Sex in Plants; and in 1916 a book on Evolution, Heredity, and Eugenics. He published from time to time papers on evolution, on various educational and religious subjects, and on topics dealing with the relation between science and religion.

Great as were Professor Coulter's contributions to taxonomy, morphology, and other fields, and as a botanical editor, it is probable that his greatest single influence was as a teacher. He was an inspiring lecturer, a splendid counselor, and a devoted friend. His kindly sympathy and help drew all his students closely to him, and made them devoted followers. He inspired many men and women to devote themselves to botanical research and botanical teaching. This was true at Hanover, Crawfordsville, Bloomington, and Lake Forest, but it was particularly true at Chicago, for there as nowhere else in his previous experience came opportunity to teach, influence, and inspire graduate students from colleges and universities from this and other countries. During his headship at Chicago 175 students attained under him the degree of Doctor of Philosophy, and almost as many attained the degree of Master of Science. Shortly after coming to Chicago he initiated the series of researches known as "Contributions from the Hull Botanical Laboratory." These include contributions made by Professor Coulter and other members of the Chicago botany staff, nearly all of the Doctor's theses, and many of the Master's theses. Nearly 400 of these have been issued in the Botanical Gazette.

The students of Professor Coulter have more than once shown their appreciaof their leader. In 1916, at the occasion of the quarter centennial of the University of Chicago, the botany doctors, then 80 in number, presented to him a volume giving the record of the doctors to that date. On December 27, 1928, at New York, there culminated a movement to establish at Chicago a John M. Coulter Research Fellowship in Botany. This movement had been initiated by the Chicago botany doctors two years previously at Philadelphia, and at New York it was announced that pledges amounting to more than $25,000 were in hand, thus assuring the fellowship. This fund was subscribed by 130 doctors and 75

masters and former students of Professor Coulter. It is expected that the first fellowship on this foundation will be available in the academic year 1929-1930. Almost simultaneously with the announcement of the Coulter Fellowship, there was presented to Mrs. Coulter a silver service and a volume of testimonials to Professor Coulter from the botanists of America. It had been the hope that Professor Coulter would be present in person to hear the announcement of the Fellowship and to receive the silver service and the volume of testimonials. It was a tragic coincidence that he died but a few days before these events were scheduled to take place. It is, however, a matter of satisfaction that before he died he was apprised of both events and was highly gratified because of them.

A scientific journal, such as the *Botanical Gazette*, is hardly the place to speak more intimately and appreciatively of Professor Coulter's life and influence, even though this is the journal that he founded and edited for so many years. It is perhaps enough to say that there has passed from us a man loved and admired, not only by his fellow botanists and former students, but also by many in other fields of science, and in every walk in life; that there has gone a great teacher, a gifted editor, an inspiring lecturer, and a facile writer; and that, as he himself said on the death of Professor Barnes, "a priceless asset has become a memory."

H. C. COWLES.

Note. Professor Coulter was one of the founders of the Indiana Academy of Science and was its second president, in 1887, succeeding David Starr Jordan. Throughout the forty-three years existence of the Academy Professor Coulter maintained an active interest in its work.—Ed.

JOHN CANDEE DEAN

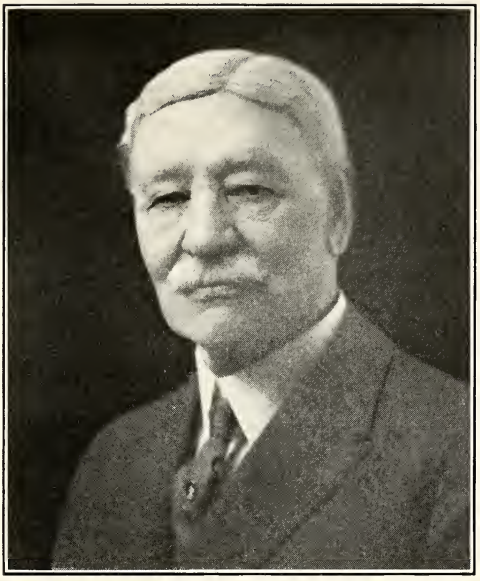
DEANSBORO, NEW YORK. September 15, 1845.

INDIANAPOLIS, INDIANA. December 31, 1928.

John Candee Dean, the son of John and Harriet R. Peck Dean, was born in Deansboro, New York, September 15th, 1845. He attended Whitestown Seminary, Utica, New York. After a short residence in New York City and Utica, he moved to Indianapolis in 1869, where with his brothers, he founded the Dean Bros. Company, manufacturers of pumps. In 1891 he married Miss Lillian B. Wright, a niece of the late Mrs. May Wright Sewall, and many were the interesting social events at their home on Pennsylvania Street. For a long time it was their custom to visit Europe every other year. After Mrs. Dean's death in 1915 Mr. Dean continued his travels in Europe and this country with Dr. Frank S. C. Wicks, a life-long friend and pastor of All Souls Unitarian Church, of which he was a member. Bashford Dean, one of the world's greatest authorities on fishes, and curator of armor at the Metropolitan Museum in New York City, was a cousin, and Mr. Dean often visited him at his home in Riverdale, New York.

At an early age Mr. Dean became interested in science and especially astronomy, and found time to contribute a monthly article on astronomy to the Indianapolis News. As a boy the writer well remembers Mr. Dean's instructive and scholarly discussions of current astronomical problems. Later, due to press of business affairs, he omitted his monthly articles, but continued to write for the newspapers until a short time before his death. He often said that his ambition was to create an interest in astronomy among the people. Farmers, school

teachers, business and professional men, as well as scientists and astronomers, consulted him on astronomical subjects. He was also a student of economics and a vigorous defender of evolution. His newspaper articles on these controversial subjects aroused widespread comment. A series of his newspaper letters so influenced public opinion that the United States government placed the



JOHN CANDEE DEAN

Federal Building in its present beautiful location, rather than on a down-town business corner. While in Europe a few years ago, he wrote a number of articles for the Indianapolis News, in which he discussed his observations on post-war Europe. He was a sincere admirer of Benjamin Franklin, whom he called "the greatest American," and, after the World War, during the period of high wages and partial idleness, he wrote a series of letters to the Indianapolis Star, advising young men to work hard, save their money, and study chemistry, physics, astronomy or geology in their leisure time, as Franklin would have advised. Benjamin Thompson, who later became Count Rumford, also commended Mr. Dean's admiration. Franklin and Thompson were both Americans who rose high in science and the counsels of European governments. Mr. Dean bitterly opposed bolshevism and was a firm believer in the capitalistic system. He always contended that man was happier and healthier under the benefits of industrialism. In a recent magazine article, he said: "The truth is that no nation has ever been pre-eminent in art, science, literature, and general culture that did not first excel in commerce."

In 1885 Mr. Dean was one of the first to observe the Nova or new star which suddenly appeared in the great nebula of Andromeda. At that time he had no telescope, so the observation was made through an opera glass.

(Astronomers have recently learned that this Nova was, very likely, the largest and most brilliant ever observed.) A few years later he acquired a fine four and one-half inch refracting telescope and for a number of years he surveyed the skies every clear night. The writer, when first attempting the difficulties of astronomical observation, well remembers the help given by Mr. Dean. He used to say that the wonders of astronomy far transcended the marvels of the Arabian Nights. He never built a private observatory, preferring the unobstructed beauty of the night. He felt that direct contact with nature was an important factor in astronomical observation.

Mr. Dean had an international reputation. His articles were published in Popular Astronomy, the Scientific Monthly, the Scientific American, the Forum, Bankers Magazine, Art and Archaeology, Chemical News, Knowledge, and the Westminster Review—the last three mentioned were English publications. He was a frequent contributor to Popular Astronomy and many of his articles were published in the Scientific American. In one case, an article entitled "Mysteries of Matter" was reprinted in several magazines, including an English publication. In this paper he argued for the theory of the flat atom, and claimed that universal gravitation is an electro-magnetic phenomenon—the latter theory has recently been confirmed by Einstein. In other articles he discussed Halley's Comet, the sun's motion through space, disruptive approach among the stars, distribution of the spiral nebulae, evolution of the stars, and many related subjects. His articles were often abridged and published in the Literary Digest and the newspapers. Theoretical questions were always clarified by his lucid discussions. His style was clear and forceful, with classic simplicity in his choice of words. He used to say that if a man could not state his facts clearly and simply he did not understand his subject. He thought that real knowledge could only be found in a knowledge of nature. In addition to purely scientific articles, he also wrote articles on sociology, economics and historical phases of astronomy and science, the last of which, "The Astronomy of Shakespeare," brought forth compliments from a prominent physicist.

He was always interested in the work of young men and often praised the work of the younger scientists. When Hubble announced a few years ago, that the spiral nebulae are external universes millions of light-years from the earth, Mr. Dean saw a new confirmation of the uniformity of natural law. He contended that the globular star-clusters are at vast distances from the earth, when more conservative opinion placed them at distances of a few hundred light-years. Now it is known through Shapley's rsearches, that the globular star-clusters are thousands of light-years from the earth. He opposed the Einstein theory of relativity, when first announced, and preferred the classical Newtonian mechanics, but, as later evidence appeared to favor Einstein, he became more tolerant toward the modern view of the universe.

Mr. Dean was a member of the Indiana Academy of Science, the Indiana Historical Society, and the University Club of Indiana. He made the University Club his home during the latter part of his life. He was a fellow of the American Association for the Advancement of Science, and in 1917 received the honorary degree of Doctor of Science from Lombard College. He was much interested in the Indianapolis Literary Club and served as its President in 1918-1919. Although his reading was principally along scientific lines, he was well versed in history and the classics, and often quoted long poems from memory. Agnostic in religion, he was tolerant of the beliefs of others, and was always the courteous

gentleman. Although in failing health during the past few years, he retained his interest in science and affairs to the end. Mr. Dean died in Indianapolis, December 31st, 1928.

RUSSELL SULLIVAN, Indianapolis, Indiana.

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JOHN STERLING KINGSLEY

CINCINNATUS, NEW YORK. April 7, 1853.

AT SEA, OFF SAN FRANCISCO. August 20, 1929.

John Sterling Kingsley, another of the pioneers of American Zoologists, has left us. While he has gone, he has left behind, among those who knew him personally, memories of a scholar, and inspiring teacher, a pleasing though highly individualistic personality, a kind gentleman, and a democrat among men.

As his middle name might imply, he was a man of sterling qualities. Trained at Williams, Princeton, and Freiburg at a time when Comparative Anatomy commanded first attention, his investigations were made in this field of Zoology, and, strange to say, even in the face of many changes in Zoological fashions, he devoted his whole life to a study of Comparative Anatomy. Due in part to these long years of application to a limited field, he became America's leading Comparative Anatomist. In addition to his contributions as a Comparative Anatomist he was an editor of note, having edited the Standard Natural History, the American Naturalist from 1884 to 1896, and the Journal of Morphology from 1910 to 1920. For a period of thirty-four years he served as professor of Zoology at Indiana, Nebraska, Tufts, and Illinois universities. In recognition of these several accomplishments he was elected to membership in many learned societies, including the Philadelphia Academy of Sciences, the Anatomische Gesellschaft, and the Zoological Society of London.

Personally when I think of Whitman, Minot, and others of that group I think of John Sterling Kingsley.

John Sterling Kingsley was born April 7, 1853, at Cincinnatus, N. Y. He died about August 20, 1929, while at sea, shortly after leaving San Francisco for a voyage around the world.

FERNANDUS PAYNE, Indiana University.

ROBERT RIDGWAY

MT. CARMEL, ILLINOIS. July 2, 1850.

OLNEY, ILLINOIS. March 25, 1929.

Robert Ridgway was early attracted by wild life. Before school age he was drawing and coloring bird pictures. He had a common school education but received an honorary degree in science from Indiana University. When he was but seveenteen years old he was appointed Zoologist of the U. S. Geological Exploration of the 40th Parallel under Clarence King. He was curator of the division of birds, U. S. National Museum, from 1880, member of the permanent

ornithological committees first International Congress, Vienna 1885, and honored by succeeding international scientific congresses, a founder of the American Ornithologists Union, its president 1898-99 and 1899-1900. He was an honorary member of a number of foreign and American Scientific Societies. A few years ago he moved from Washington to Olney where he has since made his home. At Mt. Carmel he had the help of Dr. Schneck and had known Dr. Frederick Stein, both of whom some of our elder naturalists recall at least by name. There he was visited by Wm. Brewster and they explored the cypress swamps of Knox County, Indiana. For a time he lived at Wheatland, Indiana, and gathered much information regarding the inhabitants of those swamps, both animals and plants.

His volumes on "Birds of Illinois" are in part a contribution on Indiana birds.

He was also interested in trees and plants. Years ago he bought a tract of woodland near Olney which he protected and planted with trees and shrubbery that would thrive in that latitude. He named this "Bird Haven." A committee of the American Ornithologists Union has been appointed to obtain money to secure and preserve this spot to which he gave his mind and heart in his later years.

I first met Robert Ridgway at his home in Washington many years ago and enjoyed the delightful experience.

Following the meeting of this Academy in 1925 at Terre Haute four of us accepted his invitation to visit him. Accordingly, Frank C. Evans, Crawfordsville, Indiana, President Indiana Audubon Society, O. M. Schantz, Chicago, Illinois, President Illinois Audubon Society, S. E. Perkins III., President Indiana Nature Study Club, and myself drove from Terre Haute to Olney and spent several delightful hours with Mr. Ridgway and his wife. The latter was an invalid and died some months later. Our reception will ever be a treasured memory. The welcome of the host of Larchmound was emphasized by the activities of his bird visitors. None of us had ever seen so many birds of so many different kinds about a home. A total of about 200 individuals of some 15 species were enjoying the meal the host had set before them just as we arrived. It was a splendid demonstration of what may be accomplished by proper bird encouragement.

The next morning we returned from our hotel early to find a somewhat different company of birds assembled for their breakfast.

Equally interesting, but from a different viewpoint, was our friend's study. There were copies of his books and manuscripts and pictures of birds. The latter included some of his boyhood efforts that were sent to Spencer F. Baird for identification purposes. He, like others of us who as youngsters had written Prof. Baird, received that friendly greeting and special consideration in return which we all cherish. Later with Prof. Baird and Dr. Thomas M. Brewer he wrote the "History of North American Birds" in five volumes. His final and greatest work, "Birds of North and Middle America," of which eight numbers have been published, he did not see completed.

A bibliography of Dr. Robert Ridgway's papers, containing 540 titles, was published by Harry Harris in The Condor, January-February, 1928. Indiana University published in 1905 a less satisfactory bibliography, "Indiana University, 1820-1904" which included 459 titles by Dr Ridgway on pages 321-338.

Mr. Ridgway was a member and fellow of this Academy. We honor his life, his work and his contributions to science. It is not too much to say with him passed our greatest American ornithologist.

AMOS W. BUTLER, Indianapolis, Indiana.

A CAIRN OF REMEMBRANCE

FRED J. BREEZE, Ball State Teachers College.

On May 25, 1929, the Dryer Geography Club of Ball State Teachers College, with the coöperation of the Indiana Conservation Commission, dedicated at Pokagon State Park, a cairn of large field bowlders in memory of Charles Redaway Dryer, who was widely known as an eminent teacher of geography and geology, and who was one of the first to describe the lakes and other physiographic features of northeastern Indiana.

His geological reports on the northeastern counties of Indiana are the following:

Geology of Allen County, Indiana: 16th Ann. Rept., Ind. Geol. Surv. for 1888.

Geology of Dekalb County, Indiana: 16th Ann. Rept., Ind. Geol. Surv. for 1888.

Geology of Steuben County, Indiana: Ind. Dept. of Geol. and Nat. Resources for 1891.

Geology of Whitley County, Indiana: Ind. Dept. of Geol. and Nat. Resources for 1891.

Geology of Noble County, Indiana: Ind. Dept. of Geol. and Nat. Resources for 1893.

Geology of La Grange County, Indiana: Ind. Dept. of Geol. and Nat Resources for 1893.

Great credit is due to Superintendent Bergman of Pokagon State Park for the erection of this cairn which is such a fitting memorial to the scientific work of Dr. Dryer. The cairn stands on a hill which holds a commanding position in the State Park, overlooking the beautiful Pottawattomi Inn and Lake James. The site is one of rare scenic beauty.

The dedicatory program, planned by Fred J. Breeze, Field Director of the Dryer Geography Club, is as follows:

I. Address by Dr. Stanley Coulter, Chairman of the Indiana Conservation Commission.
II. Address by Dr. Frank B. Taylor, a former student of Dr. Dryer.
III. Address by Dean L. J. Rettger, State Teachers College, Terre Haute.
IV. Ceremonial Exercises, by members of the Dryer Geography Club.

(a) Cairns of remembrance.
(b) "A Prayer of the Hill Country."
(c) "Our echoes roll from soul to soul."
(d) "Echo," a paraphrase of Thomas Moore's poem, "Echo."
(e) "The hills are shadows and they flow from form to form."
(f) "There is no Death."
(g) "God hath given Eternity to the thought of man."
(h) The message of the trumpet.
(i) Trumpet solo, from Handel's "Largo."
(j) Taps.

Many a former student of Dr. Dryer, as he walks over the hills of the beautiful Pokagon State Park, will recall the following lines from Tennyson's "In Memoriam":

"I climb the hill: from end to end
Of all the landscape underneath,
I find no place that does not breathe
Some gracious memory of my friend."

HISTORY AND RESULTS OF NATURE GUIDING IN INDIANA STATE PARKS

Sidney R. Esten, Department of Conservation

History of Nature Guiding in Indiana. Nature trails and nature guiding in their various forms over the country began in 1920 when nature trails were made in eastern state parks and nature guiding was started in the national parks of the west. The development in Indiana has not been sudden but rather slow and gradual. The movement was begun in Indiana in 1923 when through a cooperative arrangement between the Indiana Nature Study Club and the Conservation Department Miss Luci Pitschler spent three weeks of the spring at McCormick's Creek State Park. Her work the first year was concerned chiefly with children—helping them in their play, organizing games, and telling them about flowers. A few walks with the children were taken through the park and interesting birds, trees and flowers were explained to them. In the spring of 1924 and again in 1925 Miss Pitschler spent three weeks at the same park doing the same type of work. The work was not only successful with the children but gradually the adults became interested and many hikes were taken with them also. During the summer of 1926 Miss Pitschler spent three months at McCormick's Creek and continued the nature hikes with children and adults.

In the early spring of 1927 the interest in the work shown by Mr. Charles Sauers, head of the Division of Lands and Waters, resulted in a conference with Mr. Sauers, Miss Pitschler, and Mr. Sidney R. Esten in attendance, and at this meeting the first plans for organized nature work in the state parks were discussed. Later, Mr. Raymond Torrey of New York who had organized several silent nature trails in the east, stopped in Indianapolis and held a conference on nature work with Miss Pitschler and Mr. Esten. Silent trails were explained and experiences in other parts of the country with nature work were discussed. As a result of these meetings, nature trails were combined with nature guiding and the nature guide service in Indiana parks was organized. In June of that year Mr. Sauers sent Miss Pitschler to Clifty Falls, Mr. Brant Steele to McCormick's Creek, and Mr. and Mrs. Esten with two guides—Mr. Frederick Test and Mr. Otto Behrens—to Turkey Run. All were instructed to experiment with various kinds of signs and to try various methods of developing and increasing the work of the nature service. During the summer at Turkey Run not only general nature hikes were conducted but also early morning bird hikes were taken, an information bureau was organized, a nature museum was started, several silent trails and the test trail were developed and nature lectures were given.

In 1928 nature guiding was discontinued at McCormick's Creek. Miss Pitschler resigned from the service. Mr. Rexford F. Daubenmire was employed as nature guide at Clifty Falls and Mr. and Mrs. Esten with Mr. Test and Mr. Behrens remained at Turkey Run. In 1929 Mr. Esten was named chief nature guide in charge of the nature work in all the state parks. Mr. and Mrs. William Willer were sent to Clifty Falls, Mr. Stewart Springer was employed as a part time guide at McCormick's Creek, and Mr. and Mrs. Esten with Mr. Test and Mr. Daubenmire were at Turkey Run. Nature guiding was reorganized at the three parks along lines developed the previous years at Turkey Run. Nature lectures were introduced at Clifty Falls for the first time and moving pictures of nature subjects were introduced at Turkey Run.

THE OBJECT OF NATURE GUIDING IN INDIANA STATE PARKS. The state parks of Indiana abound in magnificant forms of natural beauty. Here these forms are protected, here they will remain to be seen by thousands of our future citizens when other areas are barren of many of them. People come to the state parks for the following reasons: (1) for recreation and quiet rest; (2) to study nature as it exists in the parks; and (3) because of curiosity. The majority come for the last reason. The service has little difficulty with the second group for these people are already interested in nature study, but the difficulty is in trying to interest the other two groups in the real beauty of nature. The object of the nature service is three-fold: (1) to interest as many people as possible in the natural beauties that exist in the state parks—"The Heavens declare the glory of God and the firmament showeth His handiwork." "Nature is the work of God, not man." (2) To teach people to know the various plants and animals by habits and names for "friendship and appreciation for nature come only with knowledge." "Seek and ye shall find." "Go forth under the open sky and listen to nature's teachings." (3) To cultivate sympathy, understanding and appreciation of nature. Lessons of general conservation are brought out, the need of outdoor recreation is emphasized, the value of solitude and the right use of leisure time discussed. Colleges have an opportunity to bring the study of life to only a few, but in the parks many thousands of people of all ages come under the influence of the nature guiding program. "People are made and nations are perpetuated through the right use of leisure time." "For we learn to know ourselves first of all in the mirror of the world." "Conservation means the wise use of nature's wonders." "Nature works not in miracles but in slow natural development of her wondrous beautiful forms."

RESULTS OF NATURE GUIDING AT MCCORMICK'S CREEK STATE PARK. From 1923 to 1929, inclusive, with the exception of 1928, nature guiding at McCormick's Creek under the direction of Miss Pitschler, Mr. Steele and Mr. Springer consisted mainly of nature and bird hikes. Two hundred hikes were taken with about two thousand people. The reason for discontinuing the service there for the future is the fact that the park is not large enough and the number of people attending not sufficient to warrant the maintenance of the service.

RESULTS OF NATURE GUIDING AT CLIFTY FALLS STATE PARK. Three months of each year from 1927 to 1929 under the direction of Miss Pitschler, Mr. Daubenmire and Mr. and Mrs. Willer constitute the period of work at Clifty Falls. During this time 300 general nature hikes with 4,294 people in attendance were taken and 53 bird hikes with 477 people. In 1929, 27 nature lectures were given to 1,131 visitors. Silent nature trails and test trails were maintained each of the three years. On these trails linen tags were used for the labelling of the trees, flowers, shrubs and other natural objects of interest, and on the test trails linen tags with questions were used.

RESULTS OF NATURE GUIDING AT TURKEY RUN. Nature guiding has been conducted at Turkey Run from 1927 to 1929 inclusive, under the direction of the following guides: Mr. and Mrs. Esten (1927-1929), Mr. Test (1927-1929), Mr. Behrens (1927-1928), and Mr. Daubenmire (1929). During the three years 439 general nature hikes have been taken with an attendance of 6,927 visitors, 74 bird hikes with 851 people, and 134 lectures given to 8,188 people. Information has been given to 14,000 people and it has been very carefuly estimated that about 120,000 made use of the information given on the various silent trails. The following silent trails were used: 1. Silent trails with trees, flowers, mosses and ferns labelled; 2. Conservation trail with lessons on conservation given on

the labels; 3. Tree trail with 125 of the largest trees labelled and the size of each given; 4. Historical trail of 55 labels containing the history of Turkey Run and placed on trees near the hotel; and 5. Test trail where questions were written on tags on natural objects.

When the silent trails were started linen tags were used but it was found that these last only a short time so experimentation has been conducted to find material that will last for a period of years As yet this experimentation has not determined a type of tag that is satisfactory in withstanding the elements. So far the most satisfactory are the aquaproof and the sheet metal signs and the next problem is to find a kind of paint that will not peel or wear off.

The nature museum, a feature which has been established at Turkey Run only, is a part of the program which has been given much consideration for there are great possibilities in this for future development in the state parks. Some of the objects on display are pictures of the summer birds of Turkey Run, bird nests, plaster casts of the footprints of common birds and mammals, geological specimens, samples of Turkey Run woods, fossils, moths, butterflies and some miscellaneous objects.

Summary of Results in the Three Parks from 1923 to 1929, (Inclusive). The first important result of the nature service has been the study of the flora and fauna of the three parks and the collecting of data. In 1929 Mr. Springer collected valuable data relative to the reptiles, birds and plants of McCormick's Creek area. In 1928 Mr. Daubenmire made extensive studies along these lines at Clifty Falls and Mr. Willer continued the work there during 1929 and also did some work on the study of insects. From 1927 to 1929 at Turkey Run extensive work was done among the plant and animal groups, including the fungi, mosses, ferns, flowering plants, insects, amphibians, reptiles, birds and mammals. Much help has been given at Turkey Run by visiting authorities from this and other states.

The summary of the nature guiding program in Indiana state parks is as follows:

941 general nature hikes with 13,221 people,
127 bird hikes with 1,328 people,
161 lectures with 9,319 people,
Information given to 27,000 people,
Estimated number of people using silent trails—200,000.

Thus, during the last seven years about 227,000 people have been helped by the service through information given directly or placed on tags on the silent trails, and 23,868 people have come more intimately in contact with nature through hikes and lectures. Altogether, about 250,000 people have in some way been benefitted by the opportunities given them by the nature guide service in the state parks of Indiana.

Future Plans for Nature Guiding in State Parks of Indiana. The history and results of nature guiding in Indiana show that something of real value has been accomplished in making the parks better appreciated by the thousands of visitors who have come to them. Much information gathered in the work has been given out over the state and various phases of nature work are being conducted in a similar way in city parks and in normal schools, scout camps and private grounds. A number of letters have been sent in answer to questions from other states as to the nature guiding being conducted here, and much help has been given toward establishing similar work in other states.

With the summary of the past and present come dreams and plans for the future, for nature guiding has a bright future not only in this state but in other states. In Indiana our aims are as follows:

1. To extend the service to other parks as soon as it is possible to do so, especially to the Dunes and Spring Mills.
2. To continue gathering material on the flora and fauna of the parks where nature work is carried on. This is not only necessary as a basis for successful nature work but is of scientific value for all time.
3. To develop a more extensive system of hikes whereby more people can be accommodated at one time.
4. To continue early morning bird hikes two or three times each week during the summer.
5. To develop an efficient information system in all parks so that the history of the parks, the geology and information concerning the flora and fauna may be given.
6. To establish and develop small but efficient museums at all parks where nature programs are conducted.
7. To plan and to develop better silent trails which will give information about the plants and animals of the parks as well as the history and geology of the region.
8. To continue the use of test trails so that the visitors may test their own knowledge of nature.
9. To continue experimenting with various materials and paints in order to secure better and more lasting signs for the silent trails.
10. To further develop the nature lecture program so that lectures can be given every night and will consist of illustrated colored lantern slide lectures and also motion pictures.

The continued success of the work depends upon getting new ideas and in development from year to year. Suggestions and coöperation on the part of members of the Indiana Academy of Science are urged and solicited in order to make Indiana's state parks more enjoyable to the thousands of visitors and to awaken people to the value and appreciation of Indiana's natural beauties.

THE OUTLOOK IN PHYSIOLOGY[1]

Dr. L. J. Rettger, Indiana State Teachers College, Terre Haute, Indiana

In obedience to the custom of the Academy that the retiring president "shall deliver an address," your speaker invites your attention this evening to the field of animal and human physiology with a view of noting the progress which this science is making in understanding the complex phenomena in living bodies.

Physiology is a growing science. In 1926 over 19,000 original papers were published dealing with specific problems in physiology. The report for 1929, when it is issued, will probably show over 20,000 such reports. If we throw out half of these as inconsequential and intended merely to pad professorial publishing lists, there still remain 10,000 papers dealing with original research in this field.

At the XIIIth International Physiological Congress held in Boston this last summer, over 1,200 members were present. An attendance of almost five hundred distinguished foreign physiologists, coming from thirty-five different nations of the world, shows the interest which this subject holds in the attention of men of science. That these many investigators have not been fruitless in their work is indicated by the fact that in this group of physiologists there were present three persons to whom had been awarded in former years the Nobel prize in science.

The contributions which the science of physiology is making are not at first quite so striking as some of those of physics and chemistry. The discoveries in physiology have not been translated in their applied form into aeroplanes or radios, household comforts or chemical products of outstanding commercial value. In fact, the great contributions of applied physiology are usually not credited to physiology at all, but to practical medicine. The discovery of *insulin* and its preparation in pure form is an epoch-making achievement of modern medicine and is saving the lives of innumerable persons suffering from the disease of diabetes. It is a discovery, like many others of its kind, of world significance. It is, however, seldom credited to its real discoverer, the physiologist Hedon, who in 1892 presented a brief report of some of his experiments at the Physiological Congress at Liege, reporting that he had found that the removal of the pancreas from the animals under his observation had resulted in producing an intense glycosuria, that is—an intense diabetic condition. In 1892 this simple little announcement had no practical implications and the report went almost unnoticed, but the happy discovery had been made that there was a connection between the pancreas and the ability to assimilate sugar in the body, and upon this hint other physiologists took up the investigations that finally gave us this internal chemical with which medicine has been able to conquer in large part at least, another serious human disease.

It is becoming clearer and clearer that most of the problems of disease are physiological and that even in those diseases where bacteriology and serology and clinical observations play their essential roles, the main questions are still those of functional disturbance.

[1]Address of the President at the forty-fifth Annual Meeting of the Academy of Science at Earlham College, Richmond, Indiana, December 6, 1929.

The tremendous help which physiology has given to medicine is reflected in the fact that physiology as a college study has been bodily absorbed by our medical schools. This is as it should be for the medical schools, but the science of physiology ought to be re-established in its pure form also, and be made an independent science in the curriculum of our colleges and universities. It has often been pointed out that some of the most valuable applications of science come from pure science itself and it may be that in this instance also outstanding medical applications of the future may come from laboratories not interested primarily in the strictly medical point of view.

In the second place the laity, that is, the intelligent public, must have a reasonable first-hand acquaintance with the scientific foundations in anatomy and physiology, upon which alone a larger program of personal and public hygiene can be built. Dr. Evermann pointed out to us several years ago that we had practically quit teaching Zoology in our public schools and as a result the ordinary citizen, even outside the State of Tennessee, has often only the remotest idea, if any at all, what is meant by a "species." Is it any wonder, therefore, that he can not understand what biologists mean when they speak of species and their mode of origin.

Similarly a public that has no scientific understanding of the bodily organism can not be expected to differentiate readily between the scientific physician and the medical fakir and advertising quack. Indeed the chances are that such a public will frequently take more kindly to the extravagant and assuring statements of the mountebank than to the cautious procedure of a trained health expert.

If the valuable findings of physiology are intended for our medical practitioners alone, then the medical profession will have to assume a greater responsibility in seeing that the general public is properly and scientifically informed on matters of public and personal health. Otherwise new agencies will arise to take over in a larger part the safe-guarding of our individual and corporate health. It is clear that business is determined to have workmen sound in body, and institutions of all kinds, large and small, are setting up agencies to prevent unnecessary illness in their own memberships. Insurance companies are finding that it pays enormous dividends to keep every policy holder informed of a sound program of preventive measures.

It may be that in the future, society will use its medical knowledge and its medical men to keep itself well, rather than to cure itself when sick. Fortunately increasing numbers of our physicians are meeting this new challenge and are in generous and unselfish ways leaving nothing undone to make continued health more certain and the mere curing of disease less necessary.

But it is not our purpose this evening to deal with the medical aspects of physiology. We shall leave these details entirely out of the picture and address ourselves wholly to those investigations in the field of pure physiology which make clear to us in scientific manner, how these bodies of ours function under normal conditions.

The outlook here seems so promising and so hopeful that it is somewhat difficult not to be over-optimistic. Investigations are bringing to light so many new facts of the remarkable manner in which the equilibrium of life is maintained that one may claim entirely too much as already fully established. It may be fitting, therefore, to preface this brief account of physiological achievement with a touch of humility and acknowledge at the very outset that we are facing in this field of inquiry such difficult problems that the physiologist is forced to admit

his inability to explain as yet some of the most elemental phenomena of living things.

With all the work that has been done on the physiology of "muscle and nerve" we have no clearer causal picture of the contraction of a muscle than we have of the fall of an apple to the ground. The physiologist may write volumes about contractile tissues, but he is not yet able to explain to you in the simple terms of physics and chemistry, how he crooks his finger. Much is known about the circulation of the blood but we can not yet account satisfactorily for the rhythmic beat of the heart. The directing causes that unfold the single egg-cell into the complex adult we can not explain. We can do no more than watch the unfolding mystery step by step. When it comes to such an organ or system of organs as the brain, and we try to answer how it registers sensations, retains them in memory, coördinates and transforms them into motor impulses, we are perhaps almost as far from final explanations now, as we ever were.

But not all the fields of investigation in physiology have been so refractory as those just mentioned. Of many of the living processes in the body we now have a very clear scientific understanding. At the very head of these stands probably the chapter on *respiration*. The intake of air into the lungs, its transportation through the blood stream by means of the red corpuscles in the form of oxyhaemoglobin, the release of the oxygen in the tissues, are all things that fall in completely with our known laws in physics and chemistry.

The process of oxidation in the living cells, while not quite so clear, perhaps, is now known to be governed in large part by special oxidizing ferments which make oxidation possible at low temperatures and specific for the various chemical substances in the tissue. To some extent all this can be duplicated in the laboratory.

Similarly the end products of respiration, the carbon-dioxide, the water, and other substances, are fairly well known and seem to conform in the strictest ways to known laws. We can measure the "basal metabolism" of the body with almost the same accuracy that we can measure the efficiency of an engine. The automatic stimulation of the center of respiration by the excess of carbon-dioxide in the blood is the simplest and clearest instance of the action of a hormone.

Not far behind this chapter on respiration is the chapter on the *circulation of the blood*. Since the days of William Harvey this has been a favorite field of investigation because it lends itself so readily to quantitative determination. The dynamics of the blood flow is understood with almost mathematical precision. When one considers that here we have enclosed vessels which if laid end to end, arteries, capillaries, and veins, would be literally several thousand miles in length, and note that this blood stream is kept in constant motion and makes on an average two complete circulations within the brief space of a minute, we have a system that might well excite the wonder and envy of a hydraulic engineer.

More striking though than the mere anatomical complexity of the sytem is the plasticity and adaptability of the same. Under nervous and chemical control some of the vessels may become larger or smaller, and pressures fall and rise. The central pump, the heart, can be accelerated or inhibited, to suit the necessities of the body. Internal secretions such as adrenin can powerfully affect the system. The physiologist has probaby not yet discovered all the manifold ways in which this circulatory system can be influenced, or the delicate arrangement through chemical or nervous forces by means of which the blood flow is regulated. We have but to recall the brilliant work of Professor Krogh of

Copenhagen on the capillaries to see what unworked fields still exist in such a familiar subject as the circulation of the blood.

Physiology has a third chapter in which very satisfactory progress is being made. This is the general field of *Digestion and Nutrition* and our new knowledge of the physiological *value of foods*. Our greatly increased knowledge of foods and nutrition is due to the fact that physiology has called to its aid the biochemist. Biochemistry has indeed risen to the position of an independent science, and its field has become so extended that even here no single chemist can wholly encompass it. We have gone many a mile in understanding organic compounds since the day just a hundred years ago when Wöhler first synthesized urea.

In the study of foods the greatest advances have been made in the study of the proteins. These have been taken apart step by step until we now know in fairly exact terms twenty or more of their end-products, the amino-acids and their derivities, out of which proteins are built up in varying proportions, and out of which the body, after proper digestion, rebuilds its tissues. It is probable that new end-blocks or amino-acids will be discovered and chemically determined, for there is still a protein remnant that up to this time has not responded to the chemists' analysis.

We now know that the food value of a protein depends in the main on these end-blocks which it contains. The body is unable to make these "protein neuclei" for itself and they must be furnished in foods. We also know that many of these protein neuclei or end-blocks can not be replaced by other amino-acids. As proteins differ widely in the number and amount of these end-blocks which they contain, so the problem of nutrition has become one of selecting those proteins that furnish the combinations of end-blocks best suited for the growing body.

In other words, proteins have a relative value. Thus it is possible to overeat with poor proteins and yet starve the tissues, or live on a lessened diet of proper proteins and be amply fed. The scientific dietitian of today, therefore, does not speak altogether in terms of pounds and calories, but of such a selection of foods as will furnish to the body those necessary elemental constituents, organic and mineral, without which normal growth is impossible. Of course the energy intake in foods such as fats and sugars must correspond to the outlay of work which the body is to do, but with our newer knowledge of nutrition the emphasis has changed from a quantitative study to a qualitative study of foods.

This becomes especially clear when we regard the significance of the so-called *vitamins*. What these vitamins are chemically we do not know. Thus far they have not been isolated in anything like pure form, but we know that they are easily oxidized and destroyed especially at high temperatures. We know, however, that when any one or more of these so-called vitamins are absent, serious nutritive disturbances appear in the body. In their extreme forms the symptoms are easily recognized as scurvy, or beri-beri, or polyneuritis, or sterility, but medical authorities have stated repeatedly that such nutritive disturbances in their milder forms are perhaps much more common than we suspect and that there are many more persons among us afflicted than we imagine. The great abundance of all varieties of food in this country has perhaps spared us in the main. Physiological starvation is, however, not by any means always an effect of poverty. No one can make a careful study of our present knowledge of foods and nutrition without realizing that with our national prosperity and the artificial development of our culinary art, many of us eat "in glory" instead of "in wisdom."

The present interest and importance attached to the study of the vitamins is indicated by the fact that one of the Nobel prizes awarded this year went

jointly to Professor Frederick Gowland Hopkins of Cambridge, England, and Professor Christian Eijkman of the University of Utrecht, for "pioneer work in proving the existence, usefulness, and necessity of vitamins in nutrition."

The study of the chemical changes involved in the process of digestion and nutrition has brought to the front at this time another chapter in physiology, namely, the *nature of biological ferments.* Nearly all of the chemical changes in the body are effected by specific enzymes, that is, enzymes or ferments that act, each upon a specific chemical substance only, and under the conditions obtaining in the body, split or change them chemically into other specific products, and do this with a rapidity which is surprising when one considers how slow in their action most highly complex organic substances are.

Thus we have the salivary ferments, the pepsin, the pancreatic ferments, the intestinal "erepsin" recently shown to be composed of two separate ferments, and others concerned in the digestion of foods. But these enzymes are not limited to the digestive tract. In practically every tissue and organ there are such ferments, accomplishing the specific chemical steps required in the process of nutrition, and so throughout all the living cells there are oxidations, reductions, splittings, deaminizations, and innumerable other chemical changes, effected with a swiftness and a definiteness, and under such immediate control that it may well make the ordinary chemist humble, when he considers the relatively crude chemical processes which go on en-masse in his test tube or retort.

We may liken these ferments to keys which fit special locks only, but which when properly fitted, readily unlock the combination. We are beginning to learn what the delicate molecular configurations are which make this interlocking of ferments and matrix possible. It is not altogether wrong, therefore, to say that in the tissues in which a thousand different chemical substances, completely mingled, come and go, there are carried on literally hundreds of different chemical processes side by side, yet each one largely independent of the others and specific in its results.

Much work has recently been done on the nature of ferments. Dr. Northrop of the Rockefeller Institute has just announced that an enzyme has now for the first time been crystallized. Dr. Northrop accomplished the crystallization of pepsin. It is significant that the Nobel prize in chemistry for this year, went jointly to Dr. Arthur Harden of London University and Professor Hans von Euler-Chelpin of Upsala University, Sweden, for their joint research on "enzyme action in the fermentation of sugar." That researches on ferments and vitamins should have received two of this year's prize awards indicates the interest which these fields hold.

I can not dismiss the matter of ferments without calling to your attention the recent announcement of Simon Flexner of the Rockefeller Institute that the filtrable viruses which transmit certain diseases may belong to a special class of substances of a peculiar chemical nature closely related to or perhaps identical with ferments. If this is so, then ferments approach very near to living matter, for these filtrable viruses that cause disease not only act as poisons but they grow and increase in amount, reproducing themselves. One case of small-pox may engulf an entire community. If these filtrable viruses that will pass through the very finest of Berkefeld filters are ferments, then we are not only obliged to change our concept of the nature of infection, but we shall certainly have to draw in closer lines the boundaries that are to separate living from dead matter.

While many of these ferments or enzymes have been known for a long time, there has come to light within recent years another group of chemical substances

in the body which, instead of producing immediate chemical changes, exert their influence directly upon distant organs or tissures, stimulating them to functional activity. These substances are familiar to you under the name of *hormones*, or *internal secretions*. The study of these hormones has indeed opened up one of the most fascinating chapters of physiology. It has revealed the fact that in addition to the nervous system there are ways of coördinating the different organs of the body through chemical means. While our reactions to the outside world are almost wholly under the control of the nervous system, the internal or visceral reactions are to a very large extent governed by these hormones. These are specific chemical substances liberated by one organ or tissue, thown into the lymph or blood stream and carried over the entire body. Upon most organs and tissues they are without any apparent effect, but reaching the organ for which they are specifically intended they have a profound effect upon the same.

The insulin of the islands in the pancreas makes the assimilation of sugar possible in the tissues; the carbon-dioxide produced in the acting tissues throws the center of respiration into action. Hormones generated during the period of gestation stimulate the mammary glands to functional activity so that when the little mammal is born its food supply is at hand. Hormones from the sex glands call out in the most striking manner secondary sexual characteristics. The adrenin from the adrenal glands is a powerful stimulant for the circulatory system. The pituitary gland at the base of the brain is believed to affect the matter of stature and bodily proportions. The thyroid and para-thyroid glands are known to play an important role in maintaining normal metabolism. A new hormone called eutonon, recently discovered in the liver, seems to exert an effect in maintaining the proper tonus of the heart. This list could be considerably extended if time permitted.

Some of these hormones such as adrenin and insulin have been prepared in almost pure form. It suggests the possibility of a new day in therapeutic medicine when we can have at our disposal in the treatment of disease the natural hormones in a pure state which may be concerned in that disease. It reveals that the complicated blood stream is not only an open highway for the transportation of all necessary foods and the elimination of all necessary waste products, but is also, as it were, the postal road over which organs and tissues scattered throughout the body may communicate in their own chemical language directly with one another, thus securing concerted action for common ends.

That chapter of physiology dealing with the reproductive system of the body and the manner in which the germ cells carry forward the "torch of life" from generation to generation has received so much attention and from so many different sources that it has become the important and independent *science of genetics*. The discoveries in this field have of course been striking and valuable. They are too many to be enumerated here. While we are still very far from being able to make and unmake species, to determine sex, or to add or subtract genetic characters at will, enough has been learned of the laws of heredity to warrant the hope that when these have been carefully and scientifically applied the quality of stock in the plant or animal or human being may be profoundly influenced for good.

It seems strange and worthy of note that the most important system of the body is the very one about which we know the least. This is the *nervous system* and *the brain*. Investigations have been largely limited to anatomical and histological studies. Recently, however, physiologists have addressed themselves anew to the objective and scientific study of the real physiology of the nervous

system and the brain. We are perhaps familiar with the extended work of Pavlov and his school from his recent book on "Conditioned Reflexes."

The brain seems infinitely complex anatomically, and its physiology is as yet almost wholly beyond our ken. But as light has come to most other problems by careful investigation, we have every reason to hope, though it may be at a distant time, that light will break, enabling us to understand this structure, perhaps the most complex organism in the universe.

The improper functioning of the liver, stomach and kidneys may be individually quite serious, but the improper functioning of the brain has not only individual results, it has tremendous social consequences. We need to know more about normal brain functioning so that we may find out what relation the impaired functioning of the brain bears to crime or delinquency, and if such a relation is found to exist, how normal functioning can be restored. This has been done with almost all the other organs of the body. Why should we deny this possibility to the most important organ of them all?

We still think in medieval terms about the brain and nervous system. In exactly the same way they thought about the heart and liver several centuries ago. Now we view these latter organs with clear and scientific eyes and our control over them has been extended marvelously. He would indeed be weak in his scientific faith who would not at least hope that the scientific approach to the nervous system might lead to substantial successes and that with real objective knowledge of its functionings, our social control of it would be correspondingly extended.

Yale University has just announced the establishment of a new clinic for the study of *mental hygiene*, made possible under the generous help of the Rockefeller Foundation and other agencies. A distinguished scholar and scientist has been appointed as director of it and the aim is to place our knowledge of mental hygiene upon neurological, neuro-pathological, and physiological foundations.

It has been the purpose of this paper not so much to give to you the detailed results of the recent researches in physiology, as to indicate to you where on the frontiers of this science the battle seems most active in pushing back the limits of our knowledge. Even to state the findings of a few outstanding contributions would over-tax the limits of this occasion. It has been our purpose rather to show in which directions the far-flung battle line of inquiry has been extending, and to note a few of the strategic positions that have been taken and are now being consolidated.

Of course it goes without saying that many problems other than those here indicated are being attacked. One of the newest, and it would seem one of the hardest of these problems is the scientific attempt now to go beyond tissues and organs and even cells as ultimate units, into the complex anatomical, histological, and chemical structures within the cell itself. It is certain that physiologically the cell is not the unit, but that within the cell we have contained smaller living units of such number and variety as may surprise us when we shall know more about them. We have followed the grosser changes of the chromosomes, but the chromosome itself is in all probability a very complex structure consisting of genes or bionts that in their minuteness may not differ widely from the concepts which the physicists and chemists have of molecules and atoms. In a living cell the microscope shows us a picture of threads, lines, dots, granules, and droplets of infinite shape and appeareance. It will be the duty of the cytologist of tomorrow to tell us what physiological significance this picture has. Probably

behind this microscopic picture there is an ultra-microscopic one that we shall never be able to sketch through a camera-lucida but which will have to be wrought out by painstaking experimental research a little like the physicist thinks he has wrought out the shapes of the atoms.

As in other fields so in physiology there is the apparent paradox that the more science learns about the subject the more numerous and the more involved the questions become. This fact has shown itself in a distinct trend in physiological thought at present, reflecting on the part of many leading physiologists a growing belief that a purely mechanistic theory can not account for all the phenomena of life. The laws of physics and chemistry as we now know them, seem to these investigators not quite wide enough in their reach to embrace all the phenomena in living tissues. They hold that the theories so ably advanced a few years ago and still maintained by many, that purely mechanistic reactions are sufficient to explain all biological phenomena, are no longer satisfactory and are losing ground.

I have but to recall to your mind the recent utterances of the noted physiologist Haldane of Oxford University in his new book "The Sciences and Philosophy" to indicate a growing conviction that in living physiological processes there are adjustments which transcend our present laws of the laboratory. Now these persons do not refer primarily to that supreme human question whether behind the outward functions of body and brain there exists an abiding personality of mind and spirit, for this is a question which every person will have to settle for himself on grounds other than physiological. On this point the science of physiology has not a single fact either to affirm or deny. But no matter how this supreme question may be answered by any one, the same physiological question remains—How then does the physical organism function? These physiologists have in mind biological processes of life, growth, and death as seen in living organisms throughout the plant and animal worlds.

Biology is facing the danger that such pronouncements by men of science will cause the popular thought to run into the vagaries of a discarded vitalism or an impossible supernaturalism. Surely the scientist can admit nothing less than a self-consistent universe in which finally all the fragmentary bits of knowledge will fit into one great single pattern of truth.

But it may be that we must modify and enlarge our present conceptions of physical and chemical laws. These last few years have certainly compelled us in other fields of science to question and modify accepted views that seemed to us to be the ultimate axioms upon which all future investigations would have to rest. What the physicist and chemist have been obliged to do the biologist may be forced to do also.

It may be that chemical elements lifted into higher and higher combinations of greater and greater complexity may finally reach a configuration in which new properties appear, new possibilities arise, and new laws operate. Would anyone not informed suspect that when hydrogen and oxygen unite they form such a substance as water. The two entering substances are light and are gases and subject to the laws of gases. The new substance is a liquid and the laws of gases give place to the laws of hydrostatics. That we have thus far been unable artificially to build up such living configurations is beside the point. That new living tissue can be built up only by laying it over the existing patterns of already living tissues is not unnatural. Such directing influences are familiar to the physical chemist and it suggests the idea that the physical chemist ought to be called to the aid of the biologist. Indeed this has been happening. I note

here the titles of some new books snatched at random from my library shelf: "The Colloids in Biology and Medicine," "Contributions Toward a Colloid Chemistry of Life," "Colloid Chemistry and Biology," "Physical Chemistry in Internal Medicine," "Physical Chemistry of Proteins," "The Colloid Chemistry of Egg-Albumins."

But no matter what the final and ultimate facts may be this much is certain: that at this time there is no other method of attack open to us except the scientific method of critical observation and experimentation.

I beg to close with the happy reflection that the outlook in physiology, as in other sciences, is full of promise, because the fight to push back the frontiers of knowledge in this field is going on in laboratories, in hospitals, in quiet and unnoticed places of research, in the unshaken confidence that this method which has so enriched our knowledge in the past will not altogether fail us with the multiplied problems still ahead.

If as a student of physiology I do not altogether mis-read the signs of the times, the years just ahead of us will bring us epochal discoveries in the field of biology, just as the years behind us have brought us epochal discoveries in the field of the physical sciences.

A NOTE ON THE HYBRIDIZING OF FREESIAS

W. P. Morgan, Indiana Central College

It is hard for us to realize that the modern hybrid freesia with its vivid colors, sturdy growth and pleasing fragrance is the product of the foresight of a few hybridizers who have plied their skill during the past twenty-five or thirty years. It is true that some work with this plant had been done prior to the beginning of the twentieth century but a review of the records of the Royal Horticultural Society of England and the florists' trade journals of the United States shows that very few freesia varieties were listed until after 1905. Those in existence at that time were entirely lacking in the color, size and form found in the worst of the varieties grown by commercial florists today. The many excellent qualities of the freesia and its ready response to the plant-breeders' manipulations destine it to occupy a place of ever increasing importance and popularity.

Freesia refracta Klatt was introduced into England early in the nineteenth century. (Probably in 1816 since it was first described in the Botanical Register of that year.) Aside from its attractive fragrance it offered little floricultural promise with its small, tubular flowers of a dingy, greenish yellow. At a later date a freesia possessing a "pinkish-mauve" flower was found at Humansdorp, South Africa, by a land agent named Armstrong. A white form *F. refracta alba* was introduced in England in 1878 and soon became popular as a florist's flower.

Several hybridists recognized the possibilities of the freesia. Prior to 1900 work had been mainly with pale-tinted selections from seedlings of *F. refracta alba;* also crosses with *F. leichtlinii*, a large yellow variety discovered by Max Leichtlin among some neglected seedlings in an Italian garden (about 1874). One of the first to use *F. armstrongii* in crosses with *F. refracta alba* was Dr. A. Ragionieri of Castello, Italy. At about the same time similar crosses were made at Kew Gardens, England, and by C. G. Van Tubergen of Haarlem, Holland. The results of these and subsequent crosses were several distinct strains of freesias with colors ranging from light yellow to orange, pink to deep red, brown, mauve to deep bluish-lavender, and varigated. For many years prior to his death in 1926 the Rev. Joseph Jacob continued to work with this plant and his lively writings did much to attract the attention of English plant-breeders to the freesia. His stock was taken over by G. H. Dalrymple of Southampton, for the past several years the leading freesia hybridist in England. The stock resulting from the work of Dr. Ragionieri was destroyed during the late world war. (It had been purchased and removed to France.) C. G. Van Tubergen and G. H. Dalrymple are practically the only hybridists in Europe seriously engaged in improving the freesia and their new colored varieties attract much favorable comment both in Europe and the United States.

In the United States the freesia has become popular as a florists' cut-flower. Some idea of its importance may be gained from the fact that between twenty and twenty-five million bulbs (corms) are purchased each year by florists for forcing under glass. Freesia blossoms form an important item in the cut-flower market in all the larger cities of this country during the months of January, February and March. Most of the bulbs sold for forcing are grown in the open ground in southern California.

Until the introduction in America of the variety Purity (*F. refracta alba major*) by the late Rudolph Fischer in 1909 the old *refracta alba* continued to be *the* freesia of commerce. The varieties produced by Fischer contributed materially to the increased popularity of this plant. The foremost hybridizer in the United States today is Alois Frey formerly of Indiana but now in California. Many of the colored varieties introduced to commerce during the past ten years are of Frey's originations. (Several of the varieties most popular in the United States were originated in Holland by Van Tubergen.) Although the work of Richard Bagg of Hartford, New Jersey, has attracted little attention commercially (until his production of the variety Joan Manda) it is interesting, at least historically, that he has continued his hybridizing since about 1885 when he began crossing *refracta alba* and *leichtlinii*. This probably gives Bagg seniority among all freesia hybridists in this country.

A few years ago there appeared a giant white freesia in a group of seedlings in the commercial greenhouses of Elder Brothers of Indianapolis, Indiana. This plant was a seedling from seedlings produced from varieties then in commerce. Little attention had been paid to hand pollination therefore the parentage of the giant white freesia will always remain uncertain. From the off-sets of this single plant, now registered as Elder's Giant White, a large stock of corms has been developed. So different was the Giant White from other varieties in commerce that it seemed destined to become the forerunner of a new race of freesias.

During the past three years it has been my privilege to work with this strain of freesias. Nearly fifty thousand blooming seedlings of random crosses had accumulated. The space being needed it was necessary to choose the best seedlings and discard the rest. The fact that many entirely new flower types were present made the work more interesting and difficult. Several selections from this group are now under observation and may later be introduced to commerce under name.

Our hybridizing program may best be understood by reviewing the planned crosses made during the past three years. In 1927 only three crosses, in 1928 seventeen and in 1929 one hundred seven crosses were made using the best freesia types, especially the Giant White. A cross as here referred to means the use of the pollen of one variety placed upon the stigma of another or the same variety. Often as many as one hundred blossoms were used in a single cross. Seeds of known parentage have amounted to nearly fifteen thousand in a single year. This does not include seed produced late in the season by bee pollinations. Two years are usually required to bring a seedling to maturity and at this time the best types are chosen and the rest discarded. The seedlings saved are increased by vegetative reproduction of cormels and cormlets. Although most of the crosses were made with the idea of obtaining improved flower types, nearly a third was made for the purpose of obtaining a preliminary check on genetic characters such as smooth and spiny pods, internodal lengths, color distribution, etc.

In order to make the work thorough a collection of named freesia varieties now in commerce in this country and Europe has been assembled. This now numbers fifty-four varieties produced by other originators and is probably the largest collection in this country. Several of the varieties are direct importations from Europe under special federal permit and are not to be found elsewhere in the United States. In this connection it is well to state that the freesia is relatively in its infancy when its small number of varieties is compared with

those of the Iris, Gladiolus or Dahlia. This collection of varieties is used in hybridizing and for comparison in the selection of distinct seedling types. In addition to named varieties true freesia species have been imported from South Africa. (Especial thanks is due Dr. R. H. Compton, Director of the Botanical Garden at Kirstenbosch, C. P., South Africa, for locating collectors.) Near relatives of the freesia including several Babiana species, Tritonias, Ixias, Sparaxis and Lapeyrousia are also grown in small numbers. Most of the last named forms are grown from seed collected in South Africa. A small two bench greenhouse one hundred feet long has been turned over to experimentation, and the growing of the freesia collection and young seedlings. Additional space in another house brings the total space allotted to this work to nearly twelve hundred square feet of bench surface. This does not include space devoted to the Giant White or other varieties beyond the observation stage. The attitude of Elder Brothers in providing space and equipment for my research is highly appreciated by me, especially from the fact that no effort is made to limit my work to phases having an immediate commercial outlet.

Another phase of investigation includes the cytology of the freesia and other Iridaceae. Although no report is being made at this time, sufficient work has been done to warrant the conclusion that at least one of the freesia seedlings represents a triploid chromosomal type. It is expected that reports on this and the results of other items in my investigations may be ready for publication in the near future.

ALGAE OF MONROE COUNTY, INDIANA, III

F. M. Andrews, Indiana University

Since the appearance of a paper on the "Algae of Monroe County, Indiana" in "The Proceedings of the Indiana Academy of Science" for 1926, the writer has found in this region a considerable number of forms not previously listed. Most of the forms mentioned here have been found out of doors by means of methods indicated in my former studies, but a good many others have been obtained, often in large numbers, from laboratory cultures. Material obtained from apparently very unfavorable locations has frequently produced an exceedingly vigorous growth when placed under favorable laboratory conditions. Often the presence of forms which were not indicated by immediate study of collections taken from streams and ponds later appeared in the laboratory cultures and sometimes in large numbers. Such a method will therefore act as a safeguard concerning the presence of certain species. Considerable experimentation has been carried on by the writer in other ways with certain of the forms observed. In one set of these experiments the specimens were grown in a series of nutrient solutions often with excellent results. In another set of experiments the forms were subjected to water pressure, varying in intensity from .25 to 3 atmospheres. This experiment extended over a period of from a few hours in some instances to several months in others. When good light conditions were maintained the vigor and development of specimens such as diatoms were apparently not different from the controls. More forms of desmids have been found and recorded in this list than any of the other forms. The following specimens were found:

Oedogonium Pringsheimii
Dictyosphaerium Ehrenbergianum
Mesocarpus parvulus
Spirogyra Weberi
Cladophora oligoclona
Staurospermum capucinum
Tetraspora bulbosa
Conferva bombycinia
Mongeotia minnesotensis
Lygogonum pectinatum
Stigeoclonium tenue
Ulothrix compacta
Cosmarium margaritiferum
Cosmarium Hammeri
Cosmarium schliephackeanum
Cosmarium conspersum
Cosmarium nitidulum
Closterium venus
Closterium lineatum
Closterium lanceolatum
Closterium acuminatum
Closterium juncidum
Sphaerozosma pulchellum
Docidium Rectum
Docidium giganteus
Micrasterias denticulata
Micrasterias furcata
Staurastrum Dickiei
Staurastrum Cerastes
Staurastrum arctiscon
Pediastrum Ehrenbergii
Tetmemorus Brebiasonii
Arthrodesmus fragalis
Enastrum gemmatum
Enastrum interme
Eunotia cygnus
Nitzschia bilobata
Navicula dactylis
Navicula hemiptera
Navicula cardinalis
Navicula mesolepta
Lynedra acus
Lynedra Chasei
Cymbella excisa

Penuim margaritaceum
Penuim interruptum
Desmidium aptogium
Desmidium Baileyi
Bambusina Brebissonii
Amphora Clevia
Gomphonema dichotomum

STUDIES IN POLLEN, V

F. M. ANDREWS, Indiana University

The methods previously reported in these studies on pollen have been improved as the work has been continued. The apparatus mentioned in the writer's fourth paper on this subject showed that the petri-dish method for pollen cultures was very convenient and excelled all others employed. This method was further improved on in the present investigations by using petri dishes, or low crystallizing dishes, of wide diameter. Petri dishes 12 cm. in diameter make possible the arranging and growing of 40 cultures on the under side of a single lid. These cultures were grown either with or without a cover glass, which, however, should be round and small so as to occupy as little space as possible. This arrangement enables one to make an observation ont only of a rather large number of cultures, but it conveniently places them in a small space for rapid comparison, and what is also of great importance surrounds each culture with precisely the same conditions for developing. In order to avoid possible confusion and for ease and convenience of correctly placing the cultures, it is advisable to cover the outside of the lid of the petri dish with a thin layer of paraffin and then, beginning near the periphery and moving toward the center, to make four concentric circles each one cm. apart. Ten radii equidistant from each other should be made across these four concentric circles. At the intersections of the concentric circles and radii the paraffin removed should be restored to a diameter of .5 cm. The figures showing the kind and strength of the ten solutions used should be placed on the peripheral end of the radii and then the paraffined side of the lid dipped for a minute in hydrofluoric acid. On the removal of the paraffin the desired figures and lines are left. It also affords the additional advantage that the peripheral figures serve for each circle of the different cultures under observation. The water used in the bottom of the petri dish, to maintain the necessary conditions of moisture, should be distilled water which has acquired a suitable temperature to avoid condensation. It is advisable to use petri dishes of good clear glass, free from waves, and with closely fitting lids which are provided with shims to prevent any lateral movement of the lid The word "tap water," so generally used, is also employed in these studies. By "tap water," however, as used in these investigations, is to be understood, not water as is available from the pipes in the laboratories, but suitable fresh water as is obtainable from wells or springs in the country and at places where contamination is not possible. Such water should be subjected to inspection and brought to the desired temperature before use. Of the pollen of more than 700 species of plants examined to date, only that of 180 different species germinated and grew to a greater or less extent in both tap water and distilled water. Among these may be mentioned *Trillium nivale* among monocots and *Dicentra canadensis* among dicots, in each of which only one pollen grain in 100 germinated in water. The pollen of 28 other species reacted in the same way. While the pollen of by far the greater number of species showed no germination in water, a good many

other species showed a much greater percentage of germination in water. For illustration, the numbers given for the following named plants will serve as examples and show the wide variance of certain pollens in this respect. Accordingly it was found that only 4 pollen grains in 100 of *Trillium recurvatum* germinated in water, *Amelanchier candensis* 6, *Mitella diphylla* 11, *Asclepias incarnata* 20, *Lilium tigrinum* 30, *Narcissus Tazetta* 35, *Tradescantia virginica* 50 in the sun and 70 in the shade, *Physocarpus opulifolia* 82, *Melilotus alba* and *Caragana arborescens* 90, and *Staphylea trifolia* 98. The number of germinations per hundred in water, as well as the solutions of sugar used, depend of course on the age and state of maturity of the pollen. This is very important in ascertaining the ability of the pollen to grow since the pollen of many plants is apt to be allowed to remain on, or less rarely, in the anther too long. On the other hand one may easily hesitate to gather what may seem to be pollen that is too young. This in some cases is a mistake since the pollen of some plants, as that of *Vaccinium stamineum*, may even germinate in the anther cavity. These points can, in any case of doubt, be determined with certainty only by careful experimentation. Familiarity with the pollen under investigation is essential in order to avoid mistaking foreign pollen for the one desired. Great differences are also shown by the same pollen in the different per cents of sugar. The very large pollen grains of certain species studied either showed no germination or else only a small percentage of germination as in the case of *Iris Germanica; Iris versicolor; Iris sambucina; Iris Florentina; Mirabilis Jalapa; Canna indica; Oxybaphus nyctagineus; Althaea rosea; Gossipium herbaceum; Ipomoea purpurea;* and *Hibiscus esculentus*. On the other hand certain very small grains as those of *Nelumbo lutea* and others showed a large percentage of germination in some of the sugar solutions. Of the genus Trillium 60 pollen grains in 100 of *Trillium erectum* germinated in 40% cane sugar; while in *Trillium recurvatum* the same number germinated in 15% cane sugar; but only 10 in 40% cane sugar. The next largest number of germinations in this genus was in *Trillium undulatum* where 37 in 100 germinated, followed by *Trillium grandiflorum* and *Trillium nivale* in each of which 30 grains in 100 grew, and then *Trillium cernum; Trillium declinatum* and *Trillium sessile* diminishing in the number of germinations per 100 in the order named. While variation in the percentage of germination of pollen grains is to be expected, the above mentioned figures represent the average of the growth of pollen as shown by many experiments. In some plants the quantity of pollen is very small, since *Mirabilis Jalapa* has only about 32 in each anther cavity, while in other plants the number of grains may be many thousand in a single anther cavity. Honey bearing plants have, comparatively speaking, little pollen, while plants without honey have a large amount of pollen. The large amount of pollen on the terminal cyclindrical spike of flowers of *Typha latifolia* and the catkin like masses of scales bearing the stamens of Pinus are well known. While the various parts of many plants have odor, bees seem to be able to detect odor in pollen.

A PRESSURE CELL

F. M. ANDREWS, Indiana University

The purpose of this pressure cell is for the study of entire plants or parts of rather large plants under direct observation and where water pressure of only a few atmospheres are employed. It consists of a base of wood A, 18 cm. long,

14 cm. wide, and 3 cm. thick, which has been boiled in 52°C. paraffin to prevent swelling and warping. Two cm. from each end are grooves B, 9 mm. wide and deep, which traverse the block to side grooves D, E, and F, of the same depth and width and varying in distance from the side C of the block A. All of the grooves above mentioned are on the same side of the block A and serve to hold the lower end of rectangular pieces of thick plate glass G when certain experiments are performed. In some experiments the glass plates may be dispensed with. These plates are held in position at their upper end by an adjustable zinc frame H. In this way glass plates of any length may be used. On the wood block A is placed a strong, clear glass cylinder I, 12 cm. long and 3 cm. inside diameter. This cylinder when in use is closed by a thick 2-holed rubber stopper J, whose lower end is paraffined and through which pass two tubes. One of

"A Pressure Cell"

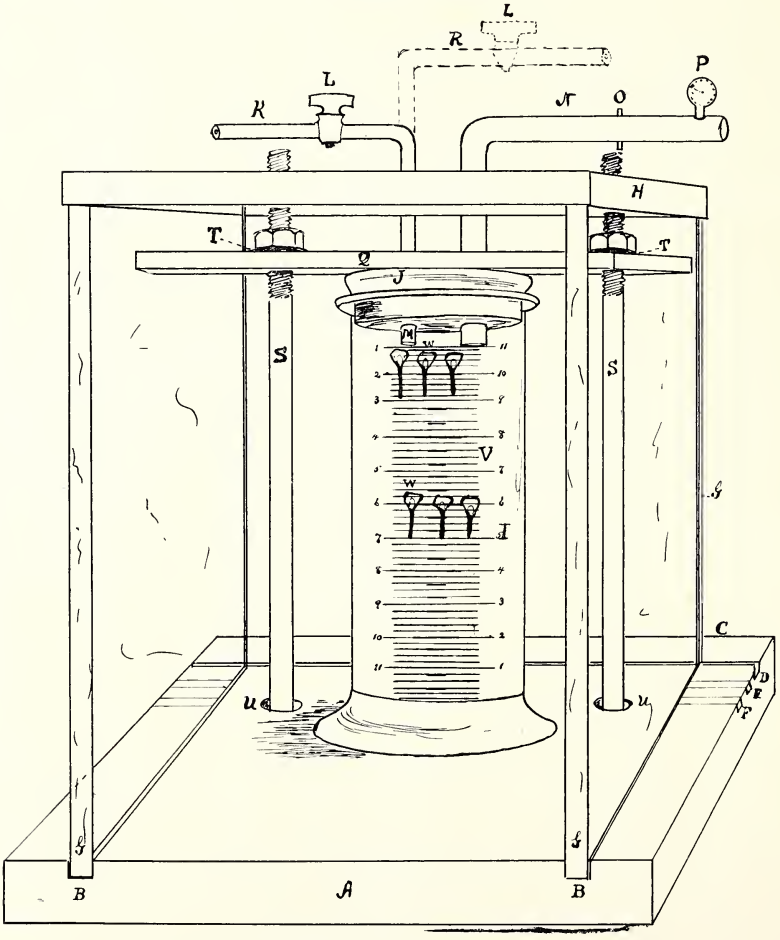

Fig. 1—A Pressure Cell.

these tubes K serves as an overflow and is controlled by the glass stop cock L. A filter is provided at M. The water under pressure enters N, which contains a filter at O and a pressure gauge at P. The rubber stopper J is held firmly in I by means of a plate Q, 120 mm. long, 65 mm. wide, and 5 mm. thick, through the center of which passes a circular opening 25 mm. in diameter to allow the passage of K and N. At the same time it allows I to be opened by removing the rubber stopper J when the brass plate Q is turned back over K and N, by turning K in the same direction as is shown for N, as is indicated by the dotted line R. Through the ends of Q pass thick brass bolts S, threaded at each end and carrying heavy brass nuts which rest on brass washers T. The lower ends of S are threaded for only one cm. from the end and are counter sunk on the lower side into A at U, while the upper ends of S are threaded back 6 cm. from the end. This arrangement affords a quick and secure method of forcing and holding, water or air tight, J. into I or the removal of J from I. The apparatus may be lengthened by the use of a longer glass cylinder, bolts and glass plates than those shown in Figure I. This is desirable in certain experiments with long plants. Water pressure is not dangerous with an apparatus of this sort, but when even slightly compressed air or gasses of any kind are used, extreme care must be exercised. Danger in this latter respect, however, is obviated in the case of low gas pressure by the use of the heavy glass plates, G. Brass has been used for Q and S, instead of iron, due to the rusting of the latter, especially in long continued experiments. For holding seedlings and various specimens, a glass slide, V, which exactly fitted I was used. This slide was finely ruled, as indicated, by means of a dividing engine. A rubber band or a cap of gypsum was used to hold the seedlings, W, on the slide, V. In some instances graduated, clear glass tubes were used to hold the seedlings. In case V is a long slide and equals the interior length of the cylinder I, and the experiment is of short duration, more than one row of seedlings, W, can be used. By means of the graduated slides and tubes used in I, the effect of pressure can be directly observed during the experiment. Exact readings may also be made with the horizontal microscope. This apparatus is being used, at present, for an extensive study of water pressure on plants.

OBSERVATIONS ON THE DWARF MISTLETOE, ARCEUTHOBIUM PUSILLUM

T. G. YUNCKER, DePauw University

The genus Arceuthobium of the family Loranthaceae includes about a dozen North American and two Old World species which grow parasitically upon coniferous hosts. The number of species recognized depends upon the specific status of some obscure forms of which sufficient materials are lacking and also upon the standing specifically of one or two forms sometimes considered of but varietal rank. The characters by which the different species are distinguished are mostly obscure and identification is often made on the basis of the host attacked. Within proper limits this may be practicable; but, as Weir has shown by inoculation experiments, the host cannot always be relied upon for the identification of the parasite.

The plants of this genus are comparatively small, ranging in length from one or two millimeters in *Arceuthobium minutissimum* from the Himalayas to ten to twenty centimeters for *A. vaginatum* from Mexico. The plants are dioecious with inconspicuous flowers. The fruits, however, become comparatively large and prominent.

Infection by Arceuthobium produces a stimulus which results in the development by the host of numerous, small, slender branches often producing characteristic witches brooms. Several such "brooms" may be developed on one tree producing an appearance which is very striking and characteristic. The result of an infection is commonly fatal to the host.

The North American species are most abundant in the western coniferous forests where they are found from Alaska to Mexico. One species, *A. pusillum*, however, is indigenous to the coniferous forests of the northeastern United States and Ontario. During the past summer the writer had the opportunity of observing a considerable number of growths of this parasite in Mackinac and Chippewa counties in the upper peninsula of Michigan and between the Canadian "Soo" and North Bay, Ontario. This species ranges from Minnesota eastward through Michigan and Ontario to Maine, New Hampshire, Connecticut and New York. The hosts which have been observed or reported are chiefly the spruces (*Picea mariana*, *P. canadensis* and *P. rubra*). Tamarack (*Larix laricina*) has also been reported in a few instances. From observations made it would seem that the black spruce (*Picea mariana*), is the principal host in Michigan and adjacent Ontario as all specimens found were on that species. It does not appear that Larix is especially susceptable. In two places tamarack trees were found growing so close to infected spruces that their branches intermingled, but, while the spruces were badly infested, the tamarack showed no evidence of the parasite even where some of the branches were in contact with a "broom" on the spruce. Similar observation was made in the case of white cedar (*Thuja occidentalis*). This plant, however, has, so far as the writer knows, never been noted as a host for *Arceuthobium pusillum*. Young and old trees seem to suffer alike from the parasite inasmuch as plants of all ages were found attacked. The parasite is able to germinate only on the younger shoots. The stems of the parasite have been reported as developing only on the upper sides of the host branches, but, while this is true in some instances, they may develop

from all sides of the branch and in the plants observed showed no tropic curvatures except in older plants bearing fruit.

The plants of *Arceuthobium pusillum*, which are olivaceous or brownish in color, are the smallest of the American species, ranging in length from two to twenty millimeters. The stems are simple or bear very short branches. They never develop the tufted appearance so characteristic of the larger western species. The stems are four-angled (often obscurely so in fresh young plants) and bear very small, inconspicuous, opposite, connate and obtuse or slightly pointed leaves. The staminate plants are commonly smaller and less robust than the pistillate. The sessile staminate flowers are two millimeters or less broad and borne two at a node with two or three ovate, fleshy calyx lobes spreading from a triangular disc. The sessile, one-celled anthers, which open transversely, are borne near the middle of the calyx lobes. The laterally compressed pistillate flowers, which are about 1.5 millimeters long, are borne on very short pedicels which elongate and become somewhat reflexed in fruit. The ovary is enclosed by the calyx tube which is two-parted at the top. The stigma is globose-pointed. The ovoid fruit becomes about three millimeters long and is an attractively bluish color. The seeds of Arceuthobium are explosively discharged to a considerable distance. Peirce observed seeds discharged to a distance of fifteen feet in a western species and believed they might be thrown to a much greater distance under proper conditions. The seeds are enclosed in a gelatinous mass when discharged which enables them to adhere to the host.

Fig. 1—A witches broom produced by *Arceuthobium pusillum* on a young black spruce near Spanish river, Ontario.

Fig. 2—A black spruce badly infested with *Arceuthobium pusillum* found near St. Ignace' Michigan. Note the large "brooms" and the dying condition of the host.

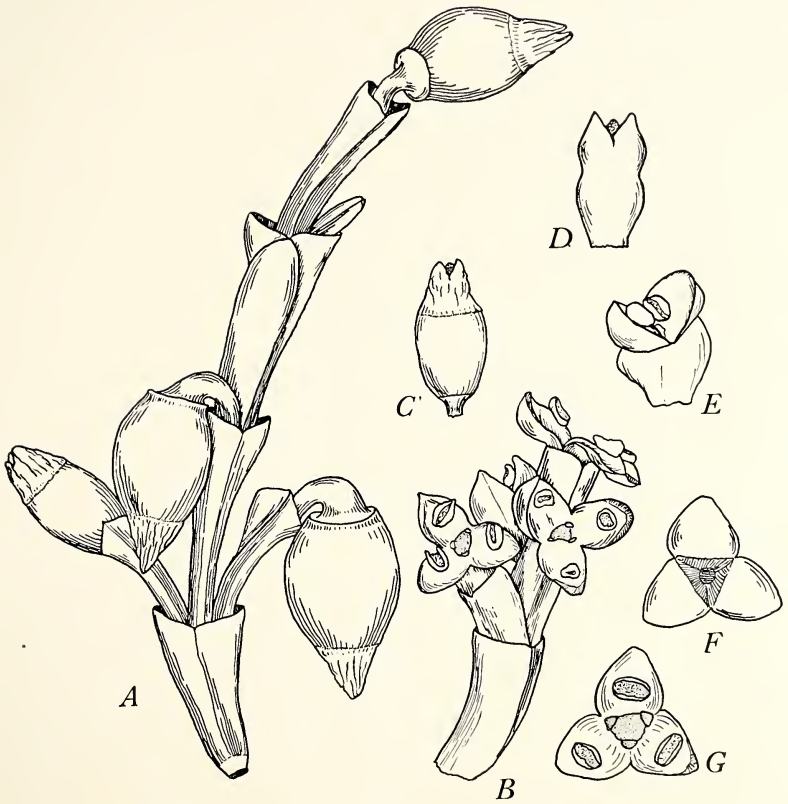

Fig. 3—*Arceuthobium pusillum* x5. A—fruiting plant; B—staminate plant; C—young fruit; D—pistillate flower; E—2-parted staminate flower; F—bottom view of staminate flower; G—top view of staminate flower.

FOREST AND PRAIRIE, BENTON COUNTY, INDIANA

Winona H. Welch, Indiana University

Benton is one of the northwestern counties in Indiana. It is bounded on the north by Newton and Jasper counties, on the east by White and Tippecanoe, on the south by Warren, and on the west by the state of Illinois. The area of the county is approximately 414 square miles. The soil is everywhere a rich black loam and is not excelled in fertility by any county in Indiana. There is not one acre of waste land in the county. The clay, lying immediately beneath the prairie loam, is of glacial origin.

There are no conspicuous elevations, but three or four prominent ridges or swells, almost parallel to each other, extend in an easterly and westerly direction across the county. Two of the most prominent ones are shown in Figure 1. Generally they are regarded as morainic ridges. The surface of the entire county is high and gently rolling, and the water flows in every direction. Gravel Hill, the highest point in the county, is three and one-half miles northwest of Fowler, the county seat, and rises almost in the center of the county. Gravel Hill is 857 feet (1) above sea level. Other high points are indicated in Figure 1. There is a range in elevation of approximately 200 feet (1) between the highest and lowest points of the county. According to Gorby (5) all the material of the drift is of glacial origin and the topography is probably due to a post glacial agency. In some places the drift is 82 feet deep and in others it has a depth of 262 feet.

The mean temperature of Benton county is 51 degrees. The annual rainfall of 39 inches is evenly distributed. The average length of growing season is 165 days.

The type of natural vegetation of Benton county is prairie. It is an extension of the Grand Prairie of Illinois. In the county there are eight natural groves. These are the result of the extension of the forest from the east toward the west. Thus a record of the species of woody plants in the groves is interesting because this county is in the transition belt between deciduous forest and prairie, although the latter type of vegetation is decidedly dominant. Due to extensive cultivation the natural condition of the Grand Prairie has not been preserved except along roadsides and railroad right-of-ways. Because of clearing and pasturing the natural conditions of the groves do not continue. This is an attempt to record and preserve data concerning the natural groves of Benton county, which with one or two exceptions are being gradually destroyed, as they occur in the only true Grand Prairie county in the state of Indiana. Although the wooded areas along Big Pine Creek were visited and the species noted, this discussion does not include them. There are eight of these "island-like" groves in Benton county.

History. In the fall of 1824 (2) a party of land hunters rode through Benton county and reported blue-stem (*Andropogon furcatus*) so high that a horseman could tie the ends over the top of his head.

About 1830-1831 (2) the first settlements in Benton county were made.

In 1862 Richard Owen (6) reported concerning Benton county and stated, "For the Geologist and Physical Geographer, the Botanist and Zoölogist, as well as the lover of scenery such as boundless vision of the day and the gorgeous sunset of the evening afford, this ocean-like prairie region, and these island-like groves are replete with interest and instruction."

History relates that in 1867 a prairie fire swept from Gravel Hill to Remington in Jasper county in about four hours. Prairie fires were almost an annual occurrence from the beginning of the county. The fire of 1867 did not touch or affect any of the groves as far as is known.

In 1870 (2, 3) there were a great many sloughs scattered through the county. The cultivated land was along the ridges and these were seepy and wet. About 1875 or 1876 (2) the first ditches were plowed through the waste land and the swamps were eliminated. Then the blue grass (*Poa pratensis*) started growing. The tile industry began about 1881 and during the next 20 years thousands of acres were prepared for cultivation. Thus there has been a gradual disappearance of the Grand Prairie species except those plants surviving along roadsides and railroad right-of-ways and a continuous decrease in the number of trees in the native groves. The latter condition has been occurring since 1880 when a saw mill was placed in Parish Grove, and the most valuable trees were cut for commercial purposes. Since that date the grove has been gradually disappearing.

In 1886 it was estimated (5) that the groves of limited extent comprised only about 3% of the area of the county, and, as reported by Gorby (5), they dotted the surface of the wide-reaching prairie and had the appearance of verdant islands lying placidly upon the bosom of some gently rolling sea.

Method. A general survey of the surface of the entire county was made by field glasses and auto in order to observe the morainic ridges and the general location of the eight groves. Following this, the species of woody plants in each grove were identified and listed and the habitats noted.

The Groves of Benton County. Sugar Grove occupies the point of land formed by the union of Sugar and Mud Creeks and extends a short distance north of Sugar Creek. It is located about five miles southwest of Earl Park and one mile from west boundary of the State. This grove consists of approximately 200 acres at the present time.

Turkey Foot Grove is located three miles east of Earl Park. Formerly there was a lake consisting of 100 acres on the south and southwest sides of the grove. Hickory Grove Lake and Turkey Foot Grove Lake were the largest lakes in the county and were wild game resorts. At the present time there are only a few acres in this grove.

North Hickory Grove is one mile directly west of Fowler. About 40 acres of the original 80 remain. In the early days of the county this grove bordered the northern shore of a 200-acre lake. The dominant plants recorded at that time were rushes, willows, and gigantic bullgrass. Hickory Grove Lake was drained completely about 1881.

Denton's Grove or Walnut Grove extends almost to the east boundary of Benton county and is located about eight or nine miles east of Lochiel. Approximately 100 acres of the grove remain, and a portion of it is in low ground.

McConnell's Grove is practically a replica of White Oak Grove and occurs on an undulation on the boundary between Benton and Warren counties, about five miles southwest of Oxford. At present there are approximately 40 acres of the grove in each of the above-named counties.

White Oak Grove is the largest in the county. Oxford has been built in this grove, and the latter extends some distance southwest of Oxford. There are about 1,600 acres at present although there were approximately 2,000 acres originally. The surface of the ground is slightly rolling and broken with a few

shallow ravines. I measured a few of the largest trees when taking notes in this grove. The measurements which follow were taken three feet above the ground: one black walnut 9 ft. 9 in. in circumference; one burr oak, 9 ft. 8 in.; and another burr oak, 10 ft. 3 in.

South Hickory Grove is located two miles northeast of Ambia. Originally this group of trees covered about 10 acres, but at present there are approximately five acres of scattered trees. A creek passes on the northwest side of the grove and boggy conditions occur just southwest of South Hickory.

Parish Grove is seven miles southwest of Fowler. In 1885 it was estimated (5) that this grove covered 700 acres of land. Now there are approximately 300 acres of trees. The surface of the land covered by this grove is not regular like that of the surrounding prairie but is broken in places by shallow ravines. There are numerous springs in this grove, and the water from these flows in the little ravines throughout most of the year. According to history one of the Parish Grove springs supplied sufficient water for the horses and travelers who passed this way in the early 40's (2). The masses of underbrush and tangled vines often barred the way of the hunters and travelers. No such condition exists now due to the processes of clearing and pasturing. According to Gorby (5) the trees in Parish Grove in 1885 were of immense size; e.g., burr oaks 5-6 ft. in diameter, walnuts 7½ ft. in diameter and 4 ft. across 70 ft. above the ground. About 1880 (2) a saw mill was placed in this grove and since that time there has been a gradual destruction of the trees for commercial purposes. The stumps of fallen trees are numerous; some of them are very large and well preserved while others are decaying rapidly. Taking the measurements three feet above the ground, one stately hackberry now measures 12 ft. in circumference, and one American elm has a circumference of 10 ft. After studying the trees in a number of local woods it becomes evident that Parish Grove is outstanding now as well as in former days in its large variety of species of woody plants, especially so for an extent of only approximately 300 acres in the prairie portion of Indiana.

There is apparently nothing peculiar about the kinds of trees growing in these groves since each species, with the exception of *Maclura pomifera* and *Robinia Pseudo-acacia* which are considered here to be escapes, commonly grows in this part of the United States (4), and each one may be found in almost any portion of the state of Indiana (4). Each species here found commonly prefers rich, moist soil, a great abundance of which is found in all parts of Benton county. The most outstanding fact is the large variety of species of woody plants growing in Parish Grove in comparison with the number in the other groves of Benton county and in similar woods in the prairie portions of Newton and Jasper counties (7, 8). There are 45 species of woody plants in Parish Grove, 32 in White Oak, 30 in Sugar, 21 in Denton's or Walnut, 8 in North Hickory, and 7 in Turkey Foot. Since the trees remaining in South Hickory are so few and scattered and since McConnell's Grove is considered to be a replica of White Oak as far as kinds of trees are concerned, these groves were not visited.

The specimens of each species listed have been mounted in book form by Mr. and Mrs. Elmore Barce and deposited in the Public Library of Fowler, Indiana, for the use of those who are increasing their interest and knowledge concerning their native trees. The specimens were collected during the summer of 1929. The nomenclature is that of the seventh edition of Gray's New Manual of Botany.

Woody Plants of Benton County Groves. In the following list of the 37 genera and 56 species of woody plants in the groves of Benton county the symbols and their meanings are as follows: P—Parish Grove, WO—White Oak, S—Sugar, D—Denton, H—North Hickory, and TF—Turkey Foot.

Acer saccharinum			S			
Acer saccharum	P					
Acer saccharum var. *nigrum*	P					
Aesculus glabra	P		S			
Asimina triloba	P		S			
Benzoin aestivale	P					
Carpinus caroliniana	P					
Carya alba		WO				
Carya cordiformis	P	WO	S	D		
Carya ovalis		WO				
Carya ovata	P	WO	S	D	H	TF
Celtis occidentalis	P	WO	S		H	
Cornus paniculata	P	WO		D		
Corylus americana	P	WO		D		
Crataegus Crus-galli	P	WO	S	D	H	TF
Crataegus mollis	P	WO	S	D	H	TF
Crataegus punctata	P		S			
Crataegus sp	P			D		
Evonymus atropurpureus	P		S			
Fraxinus americana		WO	S			
Fraxinus nigra			S			
Fraxinus pennsylvanica			S			
Fraxinus quadrangulata	P					
Gleditsia triacanthous	P					
Gymnocladus dioica	P					
Juglans nigra	P	WO	S	D		
Maclura pomifera	P	WO	S	D	H	TF
Malus ioensis	P	WO	S	D		
Morus rubra		WO	S			
Populus deltoides	P					
Prunus americana	P	WO		D		
Prunus serotina	P	WO	S	D	H	TF
Psedera quinquefolia	P	WO		D		
Quercus alba	P	WO	S			
Quercus imbricaria		WO		D		
Quercus macrocarpa	P	WO	S	D	H	TF
Quercus rubra		WO	S			
Quercus velutina		WO				
Rhus glabra	P	WO	S			
Rhus Toxicodendron	P	WO	S			
Ribes gracile	P					
Robinia Pseudo-acacia	P		S			
Rosa humilis				D		
Rubus allegheniensis	P	WO		D		
Rubus occidentalis	P	WO		D		

Salix nigra	P		S		
Sambucus canadensis	P	WO		D	
Sassafras variifolium	P	WO			
Smilax hispida	P				
Staphylea trifolia	P				
Tilia americana	P	WO	S		
Ulmus americana	P	WO	S		H
Ulmus fulva	P	WO	S		
Viburnum prunifolium	P		S	D	
Vitis vulpina	P	WO	S	D	TF
Zanthoxylum americanum	P				

Discussion. The species of trees occuring in these groves prefer moist, rich soil, and the groves have developed in such habitats. These woods have a closer relationship with water than with high ground since Parish Grove is the only one occupying a portion of ridge or swell. Each grove is or has been closely associated with a creek, with a depression such as a pond or lake, or with ground spotted with numerous springs. South Hickory, Sugar, White Oak, and Denton Groves are on the north or northeast sides of creeks or lakes. Parish Grove occupies springy ground. Although we have records stating that prairie fires occurred annually we have no record of any fire touching or affecting any of the

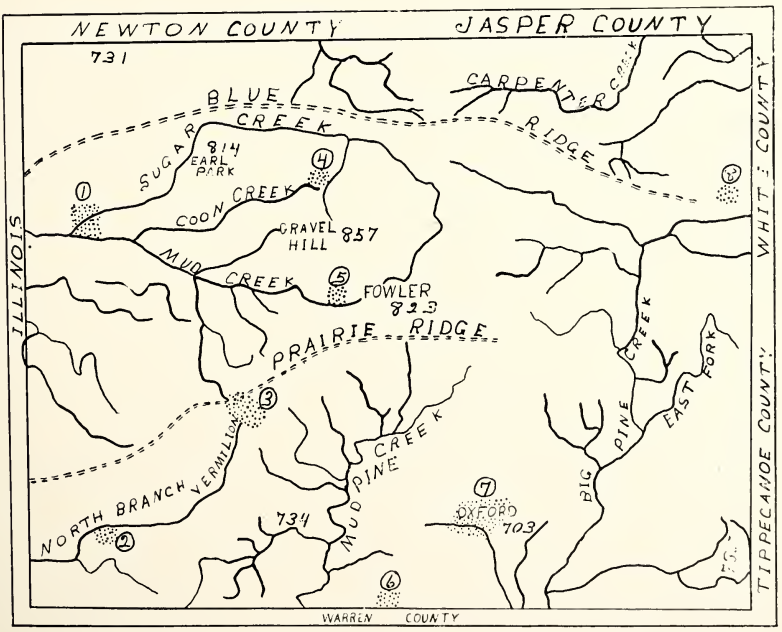

Fig. 1—Map of Benton county, Indiana, showing the location of the eight "island-like" groves in the "ocean-like" prairie. (1) represents Sugar Grove, (2) South Hickory Grove, (3) Parish Grove, (4) Turkey Foot Grove, (5) North Hickory Grove, (6) McConnell's Grove, (7) White Oak Grove, and (8) Walnut or Denton's Grove. The other figures refer to the number of feet above sea level. The remainder of the map is self-explanatory.

groves. Probably their locations protected them, more or less, from this destruction since the prevailing winds upon the prairies, particularly in the autumn, are from the west or southwest. Due to the extensive cultivation of this rich land of Benton County and to the cutting down of the larger and more valuable trees, the forested area has decreased instead of increasing.

The dominant grass in the swampy ground was *Spartina Michauxiana;* that of the higher land was *Andropogon furcatus*. The drainage ditches eventually eliminated the swamps. *Poa pratensis* grew in pastured and cultivated fields and gradually lessened and finally prevented the dangerous prairie fires. Now, valuable farms surround the groves on all sides and the prairie grasses are rarely seen.

Summary. 1. Before cultivation commenced, the type of vegetation in Benton county was prairie.

2. *Andropogon furcatus* (Tall Blue Stem) was the dominant upland grass, and *Spartina Michauxiana* (Slough Grass) was dominant in the low lands or wet prairies.

3. Eight native groves mark the extension of the forest into this prairie county. Orginally they comprised only 3% of the entire area of 414 sq. miles.

4. The forested areas have developed in moist habitats on the north or northeast sides of creeks or lakes or on ground watered with springs. Here they have been supplied with sufficient water for their proper growth and have been protected from the annual fires which came from the west and southwest and swept across the prairie.

5. Due to extensive cultivation the prairie grasses have almost disappeared.

6. Due to pasturing, clearing, and farming, the forested areas are decreasing in extent and development.

7. There are 37 genera and 56 species of woody plants in the native groves of Benton county. Parish Grove with 45 species has the largest representation of any grove.

8. *Acer saccharum* is a rather frequent species in Parish Grove but *Fagus grandifolia* was not found in the county and never has been reported. Therefore the groves are not considered as climax forest.

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A WILD FLOWER SANCTUARY ON THE TIPPECANOE

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The writer has recently set aside twenty-four acres of land on the Tippecanoe River as a sanctuary for the wild flowers of Indiana. This tract of land, situated near the western edge of Carroll County, lies four miles northwest of Delphi and six miles east of Brookston. About one half of it consists of a steep bluff which rises to a height of seventy-five feet above the river. The other half is level upland adjacent to the bluff.

This bluff is at the outer side of the large horseshoe bend of the Tippecanoe. Locally, this steep slope has been known as Cedar Bluff, because of the abundance of red cedars there. At the present time the deciduous trees seem to be crowding out the cedars. At one point on the bluff is a large spring.

It is the intention of the writer to place in this garden many of the species of wild flowers that are rapidly becoming extinct in Indiana. Many native shrubs also will be planted to furnish food for the birds in the winter time. It is hoped that this wild garden may become a place of refuge for birds as well as for plants.

This sanctuary is to be named Powys Gardens. The word, Powys, is the ancient name of that part of Wales which was the birthplace and boyhood home of the owner.

INDIANA FUNGI, XII

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MYXOMYCETES

Clastoderma Debaryanum Blytt. On dead fallen limb, Cedar Cliff, Monroe County, July 14, 1929. L. B. Lockwood. I. U. 5212.

Fuligo septica (L.) Gmel. form *F. violacea* Pers. On stump, Brown County, June 30, 1929, Zetterberg. I. U. 5083. On live petioles of *Plantago* and *Viola*, University campus, July 11, 1929. Otho Shaw. 5097. On sawdust walk, campus, July 14, 1929. Stech. I. U. 5196.

Lycogala epidendrum (Buxb.) Fr. On rotten wood, Posey County, July 5, 1929. Shaw. I. U. 5090.

Stemonitis Morgani Pk. On decayed wood, Hamilton County, July 28, 1929. Groves. I. U. 5213.

PHYCOMYCETES

Pythium Debaryanum Hesse. On seedlings of *Lilium regale* Wils., I. U. conservatory, March 4, 1929. Mottier. I. U. 5012. (This fungus was the cause of severe "damping off" of seedlings. Stirring the soil and sprinkling it with sulphur proved effective.)

ASCOMYCETES

Bulgaria inquinans (Pers.) F. On buried sticks, Decatur County, July 5, 1929. Zetterberg. I. U. 5088.

Caryospora putaminum (Schw.) De Not. On old peach pits, Bedford, Lawrence County, June 1, 1929. Sears. I. U. 5028. More of these were collected August 4, 1929, when the fungus was found to be mature. I. U. 5210.

Chlorosplenium aeruginosum (Oud.) De Not. On rotting log of *Liriodendron tulipifera* L., Stephens Creek, Monroe County, April 20, 1929. Jackson. I. U. 5023. Apothecia numerous under the log. Although wood of oak and yellow poplar stained green by this fungus is very common throughout our area, the apothecia, which are of a verdigris-green color, often escape notice, as they seem to favor darkness. They are usually found under logs, beneath bark, etc. In England, this "green oak" is used in the making of Tunbridge ware. Wood is often stained quite evenly a beautiful mission green. Specimens of wood more or less exposed to light for some twenty years, still retain the color well.

Cordyceps palustris Berk. & Br. On small white grub, Stone Springs, Monroe County, April 20, 1929. Sears. (Conidial state.) I. U. 5026.

Exoascus mirabilis Atk. On developing buds of *Prunus hortulana* Bailey, Monroe County, July 4, 1927. I. U. 5254. This disease was observed each spring from 1915 to 1927 in a large thicket of these wild goose plums, where almost all developing buds were hypertrophied. The hypertrophied growth dies in June and is covered with a dark mold. Some axillary buds then develop. I have never seen any occurrence of this fungus on the fruits.

Hypoxylon coccineum Bull. On bark of dead *Fagus grandifolia* Ehrb., Montgomery County, summer of 1928. A. R. Bechtel. I. U. 5069.

Hypoxylon fuscum (Pers.) Fr. On *Acer saccharum* Marsh., July 27, 1929. Zetterberg. I. U. 5184.

Hypoxylon Morsei B. & C. On bark of living *Rhus vernix* L., in a cranberry bog, near Elmdale, Montgomery County, April 15, 1929. A. R. Bechtel. I. U. 5075. Probably not a pathogene, but occurring on an area already dead.

Hypoxylon serpens (Pers.) Fr. On a piece of driftwood (*Ulmus*), Sugar Creek, Montgomery County, April, 1929. Bechtel. I. U. 5074. This specimen corresponds extraordinarily well with published description. We have identified this species only once before. In 1913, it was collected by G. B. Ramsey in Boone County on red oak. It was never observed by Owens in his thorough study of the genus *Hypoxylon*.

Lachnea scutellata (L.) Gill. [*Patella scutellata* (L.) Morg.] Seaver, N. A. Cup-Fungi, p. 159. On rotting stump of *Acer saccharum* Marsh., campus, May 11, 1929. I. U. 5039. Collected again on this same host, October 10, 1929. I. U. 5241.

Microsphaera Alni (Wallr.) Wint. On *Evonymus atropurpureus* Jacq., Monroe County, September 20, 1920. I. U. 5221. Very common each year. The conidial stage coats the entire upper surface of the leaves.

Morchella esculenta (L.) Pers. On ground, Steuben County, May 24, 1929. I. U. 5047.

Phyllactinia corylea (Pers.) Karst. On leaves of *Quercus rubra* L., Brown County, October 30, 1927. Amidei. I. U. 4947. October 27, 1929. I. U. 5266.

Rhytisma punctatum (Pers.) Fr. On leaves of *Acer saccharum* Marsh., Borden, Clark County, October 12, 1929. I. U. 5247. Though occurring on older trees, this fungus did much injury to the foliage of hundreds of seedlings (two feet and under) in an old woods-pasture which had been abandoned for the first time. This is the first case of actual damage from Rhytisma observed by the author.

Rosellinia aquila (Fr.) De Not. On bark of decaying stick, Binford's woods, near Crawfordsville, Montgomery County, April 1929. A. R. Bechtel. I. U. 5072.

Sphaerotheca Humuli (DC.) Burr. On *Rosa*, Daviess County, July 5, 1929. Stech. I. U. 5093.

Valsa fulvella B. & Rav. On bark of *Platanus occidentalis* L., Ladoga, Montgomery County, September 16, 1913. G. B. Ramsey. I. U. 4994.

Xylaria Hypoxylon (L.) Grev. On old maple (*Acer saccharum* Marsh.) stump, campus, April 18, 1929. I. U. 5027.

BASIDIOMYCETES

USTILAGINEAE

Sorosporium Syntherismae (Pk.) Farl. On *Cenchrus caroliniana* Walt., Porter County, October 12, 1929. Weatherwax. I. U. 5251.

Sphacelotheca Sorghi (Lk.) Clinton. On kernels of *Sorghum vulgare* Pers. (var. Kaffir corn), university garden, October 10, 1929. I. U. 5246.

Urocystis Anemones (Pers.) Schroet. On leaves of *Hepatica acutiloba* DC., State Park at Turkey Run, Parke County, May 29, 1929. A. R. Bechtel. I. U. 5068.

Ustilago perennans Rostr. On spikelets of *Arrhenatherum elatius* (L.) Beauv., campus, August 2, 1929. Weatherwax. I. U. 5202. Clinton (Ustilaginales in N. A. F., p. 7, 1906), says: "Mycelium perennial in perennial parts of the host." Inasmuch as our plants were grown from seed from Colorado, the smutted parts must have originated from spores on the seed or from dormant mycelium in the seed-coat or embryo.

UREDINEAE

Dicaeoma canalicultum (Schw.) Ktze. On leaves of *Cyperus esculentus* L., Montgomery County, October 29, 1929, Haas. I. U. 5259. (Uredinia and telia.)

Dicaeoma Grossulariae (Schum.) Kern. Common on *Ribes*, La Grange County, May 24, 1929. I. U. 5049. Also in Steuben County.

Dicaeoma Impatientis (Schw.) Arth. On *Impatiens pallida* Nutt., Huckleberry Ravine, Monroe County, July 23, 1929. Lockwood. I. U. 5209.

Kuehneola obtusa (Strauss.) Arth. On *Potentilla canadensis* L., Washington County, March 23, 1929. Hamlin. I. U. 5016.

HYMENOMYCETINEAE

THELEPHORACEAE

Craterellus Cantharellus (Schw.) Fr. On ground, Clay County, July 13, 1929 Shaw. I. U., 5113; July 28, 1929, I. U., 5181.

Thelephora Schweinitzii Pk. On ground, Clay County, July 28, 1929. Shaw. I. U. 5182.

POLYPORACEAE

Boletinus porosus (Berk.) Pk. *Boletinellus merulioides* (Schw.) Murr. Mycologia, I, p. 7, 1909. Growing on a lawn, Goodland, Newton County, October 31, 1929. Beale. I. U. 5268.

Boletus bicolor Pk. Rep. 24, p. 78. *B. dichrous* Ell. Bull. Torr. Bot. Club, III, p. 109. *Ceriomyces bicolor* (Pk.) Murr. Monroe County, July 23, 1929. Zetterberg. I. U. 5170. These specimens exhibit characters of both *B. bicolor* and *B. dichrous*. The stem, like the cap, is red (vinaceous-rufous) as Peck has described for *B. bicolor*. Murrill has, correctly, made the two synonyms, but fails to state the red character of the stem which shows in our specimens. The pileus here is doubtfully viscid; spores ochraceous-brown, oblong, 10 to 17.5 by 4 to 5 microns (average about 14 by 5), bent at one end as Peck says for *B. dichrous*.

Boletus eximius Fr. On ground, Weimar's Lake, Monroe County, July 13, 1929. Lockwood. I. U. 5108.

Boletus subglabripes Pk. Monroe County, July 17, 1929. Lockwood. I. U. 5146.

Boletus subvelutipes Pk. On ground, Decatur County, July 21, 1929. Zetterberg. I. U. 5153.

Favolus canadensis Kl. On *Fraxinus americana* L., campus, in woods, on dead limbs attached and fallen. Very fine specimens. May 15, 1929. I. U. 5040.

Polyporus arcularius (Batsch.) Fr. On *Fraxinus*, Steuben County, May 24, 1929. I. U. 5046.

Polyporus cinnabarinus Fr. On log of *Quercus velutina* Lam., Clay County, June 23, 1929. Shaw. I. U. 5061. Laporte County, 4997.

Polyporus cinnamomeus Jacq. On ground in woods attached to underground roots, Decatur County, July 21, 1929. Zetterberg. I. U. 5151.

Polyporus conchifer Schw. On dead fallen limbs of *Ulmus americana* L., near Freedom, Owen County, November 5, 1929. I. U. 5273.

Polyporus cuticularis Bull. On dead tree of *Fagus grandifolia* Ehrb., Clark County, October 12, 1929. I. U. 5260. Spores oval, one-guttulate, yellowish-brown, smooth, 5 by 6 microns. This species was also collected on the same host in Brown County, October 27, 1929. I. U. 5267.

Polyporus gilvus Schw. On wood, Decatur County, July 21, 1929. Zetterberg. I. U. 5152.

Polyporus hirsutus Wulfen. On wood, Clay County, June 23, 1929. Shaw. I. U. 5066.

Polyporus hispidus Bull. On dying tree of *Acer rubrum* L., Bloomington, Monroe County, 1928 and 1929. Fruits abundantly, and apparently is hastening the death of the tree. I. U. 4953.

Polyporus lucidus Leyss. On wood, Posey County, July 5, 1929. Shaw. I. U. 5089.

Polyporus sulphureus (Bull.) Fr. var *Overholtsii* Rosen. On ground about four feet from a large tree (*Quercus rubra* L.), in an old woods, July 14, 1929, Clay County. Shaw. I. U. 5118. Composed of very many pileoli, the whole mass being about 40 cm. in longest diameter. This is certainly a beautiful specimen. Rosen's unusually fine description of this variety, reads as if written from our specimen (A Pink-colored form of Polyporus Sulphureus and Its Probable Relationship to Root-rot of Oaks. Mycologia, 19, p. 191, 1927.)

Strobilomyces strobilaceus (Scop.) Berk. On ground in woods, Clay County, July 28, 1929. Shaw. I. U. 5178.

AGARICACEAE

Amanita chlorinosma Pk. Campus, under trees, June 19, 1929. I. U. 5060. A second lot of specimens was collected on campus, growing in raw clay, July 29, 1929, by Gladys Jackson. I. U. 5176. These were unusually large plants. The odor of all these plants is very strong, resembling, however, that of strong turnips or horse-radish, rather than that of chlorine or chloride of lime. *A. solitatia* Fr., *A. strobiliformis* Vittad. and *A. chlorinosma* Pk. seem too closely allied. Yet, the odor is said to be the deciding character.

Amanita chlorinosma Pk. (*solitaria* form) Clay County, July 27, 1929. Shaw. I. U. 5175.

Amanita spissa Coker. Huckleberry Ravine, Monroe County, July 17, 1929. Zetterberg. I. U. 5137.

Claudopus nidulans (Pers.) Pk. On old log, Montgomery County, October 20, 1929. Haas. I. U. 5256.

Collybia dryophila Bull. Monroe County, July 15, 1929. I. U. 5052. This well knows species does not appear to be common in this locality.

Collybia platyphylla Fr. On stump, Clay County, June 23, 1929. Shaw. I. U. 5064.

Coprinus atramentarius (Bull.) Fr. On ground, gregarious, yard, in Bloomington, Monroe County, April 25, 1929. Campbell. I. U. 5031. One of our most delicious mushrooms. Common, but not heretofore reported from this locality.

Coprinus quadrifidus Pk. On old stump of *Acer saccharum* Marsh., campus' July 19, 1929. Jackson. I. U. 5149.

Lactarius affinis Pk. On ground, Clay County, July 14, 1929. Shaw. I. U. 5115.

Lactarius piperatus Fr. On ground in woods, Clay County, July 28, 1929. Shaw. I. U. 5179.

Lepiota americana Pk. On ground, Clay County, June 23, 1929. Shaw. I. U. 5063.

Lepiota naucina Fr. Field near Donalson's Cave, Lawrence County, September 21, 1929. Haas. I. U. 5222. Typical, but extra large. One specimen measured as follows: pileus, 12 cm., stipe, 14 mm. thick with bulbous base 2.5 cm. thick. The large size may have resulted from the location on heavily fertilized ground under young apple trees. Even larger ones were reported by the collector, Mrs. Haas.

Panus rudis Fr. On stump of *Acer saccharum* Marsh., Grass plot, Monroe County, April 25, 1929. I. U. 5032.

Paxillus panuoides Fr. On decaying stick in Mayfield Cave, August 3, 1929. Shaw. I. U. 5206.

Pholiota adiposa Fr. On old log, Montgomery County, October 20, 1929. Haas. I. U. 5257.

Pholiota cerasina (Pk.) Sacc. On old stump of *Fagus grandifolia* Ehrb., campus, April 25, 1929. Lockwood. I. U. 5019. Very caespitose. Determination verified by Kauffman.

Pholiota squarrosoides Pk. On old log, Montgomery County, October 20, 1929. Haas. I. U. 5258.

Pleurotus atropellitus Pk. On decorticated log on hill-top, city water-works, February 23, 1929. Lockwood. I. U. 5009.

Russula Mariae Pk. On ground, Clay County, July 14, 1929. Shaw. I. U. 5111.

GASTEROMYCETES

Calvatia maxima (Schaeff.) Morgan. *Calvatia gigantea* (Schaeff.) Batsch. In woods, lower hill-side, Griffey Creek, Monroe County, autumn of 1914. F. Donaghy. I. U. 5253. In Carroll County, where a photograph was made by Weatherwax showing a "fairy ring" some 35 feet in diameter. This species is also reported from Grant County by J. H. Ayres where it was growing in a ravine.

Crucibulum vulgare Tul. On corn-cob, near Cedar Cliff, Monroe County, July 14, 1928. Lockwood. I. U. 5170. On the same host, Owen County, November 5, 1929. Hughes. I. U. 5272.

Ithyphallus Ravenelii (B. & C.) E. Fischer. *Dictyophora Ravenelii* (B. & C.) Burt. On old decayed stump, Owen County, November 5, 1929. Hughes. Known by its membranous veil which seldom reaches below the cap. The entire corded mycelium is of a beautiful lilac tint. I. U. 5271.

FUNGI IMPERFECTI

SPHAEROPSIDALES

Ascochyta Pisi Lib. Conidial stage of *Mycosphaerella pinodes* (Berk. & Blox.) R. E. Stone. On pods of fresh *Pisum sativum* L., shipped from California. Market, in Bloomington, Monroe County, May 1, 1929. I. U. 5037.

Phoma glandicola (Schw.) Cke. On acorns of *Quercus alba* L., Turkey Run state park, Parke County, May 1, 1929. A. R. Bechtel. I. U. 5073.

Phyllosticta Asiminae Ell. & Kell. On *Asimina triloba* Dunal. Under pine, campus, August 7, 1929. I. U. 5215. An exceptionally interesting form of spots were present on these leaves. They occurred in rows near the secondary veins, coalescing to form lines one-eighth by two inches. These were evidently secondary spots formed by spores washing down the vein grooves on the upper leaf surface and germinating in the moisture there. It is common in this species, for leaves to be cut or lacerated by these spots in early summer. The spots then cease to spread, and fall out. The remaining part of the leaf (often cut entirely in two), is green until autumn. It is impossible to determine the original cause of the injury at this stage.

Phyllosticta Convallariae Pers. On leaves of *Smilax hispida* Muhl., Griffey Creek, Monroe County, July 23, 1929. Lockwood. I. U. 5194. The description in "N. A. Phyllostictas" by Seaver, corresponds well. We find another spore on these spots. This may be another *Phyllosticta*. These spores are hyaline, long ovate to elongate, 15 to 25 by 5 to 7 microns. These are probably not young asci, such as those that have, in certain cases, been mistaken for large spores.

Phyllosticta indianensis Van Hook. Ind. Acad. Sci. 37, p. 132, 1928. Van Hook, J. M., Some New Species of Fungi. On leaves of *Rosa setigera* Michx., campus, October 1, 1917. I. U. 3855. The main distinguishing characters of this species are the small spots (which resemble those of the well-known Septoria Rubi West.), the few pycnidia, and the granular thick gelatinous coated spores.

Phyllosticta Labruscae Thuem. Conidial stage of *Guignardia Bidwellii* (Ell.) Viala & Ravaz. On leaves of *Vitis cordifolia* Michx., May 31, 1929. I. U. 5056, and on leaves of *Psedera quinquefolia* (L.) Greene, June 5, 1929, Posey County. Shaw. I. U. 5054. On leaves of *Vitis aestivalis* Michx., Brown County, June 30, 1929. Zetterberg. I. U. 5081.

Phyllosticta limitata Pk. On leaves of *Pyrus malus* L., Morgan County, October 19, 1924. Leaves covered with this fungus. On an old tree in hollow, surrounded by forest.

Phyllosticta Linderae E. & E. On leaves of *Benzoin aestivale* (L.) Nees. Huckleberry Hills, Monroe County, July 23, 1929. Typical of other local specimens, but spores show no guttulae. The spores are mostly 2 to 3 by 4 to 5 microns.

Phyllosticta liriodendrica Sacc. Conidial stage of *Sphaerella liriodendrica* Cke. On leaves of *Liriodendron tulipifera* L., Brown County, June 30, 1929. I. U. 5080. Zetterberg.

Phyllosticta melaleuca E. & E. On leaves of *Ulmus fulva* Michx., Posey County, July, 1928. I. U. 5156.

Phyllosticta Rosae-setigerae Van Hook. Rep. Ind. Acad. Sci. 37, p. 132, 1928. Van Hook, J. M., Some New Species of Fungi. On leaves of *Rosa setigera* Michx., Matlock's Woods, October 1916. I. U. 3714. On *Rosa*, Showers' farm, August 23, 1920. I. U. 3804.

Phyllosticta verbascicola Ell. & Kell. On living leaves of *Verbascum Thapsus* L., Monroe County, July 18, 1927. Lois Stump. I. U. 4769. This material is typical of description by the authors. This species was also collected by Lockwood in Monroe County, July 23, 1929. I. U. 5200. In this material, we find the pycnidia mostly epiphyllous, with definite pore about 15 microns

in diameter and spores apparently hyaline, but sub-hyaline in mass and irregularly guttulate.

Septoria Bromi Sacc. On *Bromus secalinus* L., Posey County, May 28, 1929. Shaw. I. U. 5158.

Septoria Convolvuli Desm. On *Convolvulus sepium* L., June 18 to 24, 1929, campus of I. U. 5154. Spots numerous, circular, light yellowish-brown with paler center, small at first, reaching a diameter of 3 to 4 mm., visible on both sides of the leaf; pycnidia yellowish-brown, becoming darker, thickly scattered over the spot, 75 to 100 microns, pore about 20 microns; spores rod-shaped, somewhat pointed on both ends, 2 to 3-septate, straight or sometimes curved, 1 to 2 by 25 to 53 microns, guttulate.

Septoria Erigerontis B. & C. On leaves of *Erigeron annuus* (L.) Pers., Posey County, June 1928. Shaw. I. U. 5058.

Septoria Helianthi Ell. On leaves of *Helianthus annuus* L., Posey County, May 28, 1929. Shaw. I. U. 5054.

Septoria incarnata E. & E. On leaves of *Asclepias syriaca* L., Posey County, June 1928. Shaw. I. U. 5159.

Septoria Lactucae Pass. On *Lactuca scariola* L., Posey County, June 1928. Shaw. I. U. 5162.

Septoria Oenotherae West. On *Oenothera laciniata* Hill., May 28, 1929, Posey County. Shaw. I. U.? 5059. The spores vary considerably in size here as is common in our Indiana material. According to Shaw, they are 35 to 70 microns long.

Septoria polygonorum Desm. On *Polygonum pennsylvanicum* L., Posey County, June 5, 1929. Shaw. I. U. 5160.

Septoria Verbenae Rob. & Desm. On leaves of *Verbena hastata* L., Posey County, June 1928. Shaw. I. U. 5155.

Sphaerographium Fraxini (Pk.) Sacc. On twigs of *Fraxinus*, Binford's woods, Montgomery County, April 1929. A. R. Bechtel. I. U. 5071.

Vermicularia Podophylli Ell. & Dear. On fruits of *Podophyllum peltatum* L., campus, Monroe County, July 16, 1929. I. U. 5134. Spots two, 1.5 cm. in diameter, center black (from the colored epidermis and setae on the pycnidia), with a brown border; pycnidia 100 to 200 microns, "conico-hemispherical," with very dark setae 50 to 275 by 4 to 9 microns (mostly about 5 wide), long tapering, pointed or rounded at tips where they are much paler, sometimes with spherical or irregular enlargements here and there. (The two line description in Saccardo, vol. 11, p. 504, is splendid for our specimens.)

MELANCONIALES

Colletotrichum Lindemuthianum (Sacc. & Magn.) Bri. & Cav. On string beans (*Phaseolus vulgaris* L.,) in market, shipped from California, May 11, 1929. (The conidial stage of *Glomerella Lindemuthiana* Shear.)

Cylindrosporium Padi Karst. Conidial stage of *Coccomyces hiemalis* Higgins. On *Prunus serotina* Ehrb., Gibson County, July 5, 1929. I. U. 5091. Lockwood. Also on cultivated *Prunus* (cherry), Montgomery County, June 29, 1929. Sidney Esten. I. U. 5078, 5079.

Gloeosporium Caryae Ell. & Dear. Conidial stage is *Gnomonia Caryae* Wolf. On *Carya* leaves, Clay County, July 28, 1928. I. U. 5183. Shaw.

Gloeosporium caulivorum L. Kirch. On leaf-petioles, flower-stalks, etc., of *Trifolium pratense* L., late spring of 1910, north of Bloomington, Monroe

County, causing much injury, but not noticed in later years. Causes leaves and flowers to bend down. I. U. 5013. Photographs. (See Zeit. 12, 281, 1902. Ind. Acad. Sci. 37, 1927.)

Marssonia Juglandis (Lib.) Sacc. The conidial stage of *Gnomonia leptostyla* (Fr.) Ces. & De Not. On leaves of *Juglans nigra* L., Posey County, May 31, 1929. Shaw. I. U. 5057.

Pestalozzia funerea Desm. On dead spot in leaf of *Sassafras variifolium* (Salisb.) Ktze., Clay County, July 28, 1929. I. U. 5180.

HYPHOMYCETES

Aspergillus flavus Link. On cotyledon of Lima bean seedling, I. U. conservatory, February 14, 1921. Andrews. I. U. 4999. Causing decayed spots. This material was submitted to Dr. C. Thom, who placed it in the *A. flavus* section and described it as follows: "yellow-green—a fairly light shade—with spores 4 to 6 microns in diameter, yellow-green in color, walls thin and pitted, has stalks ranging from 5 to 8 microns in diameter at base and 7 to 15 microns in diameter upward with walls uncolored and pitted."

Cercospora Cynoglossi Van Hook. Rep. Ind. Acad. Sci. 37, 1928, p. 131. Van Hook, J. M., Some New Species of Fungi. On living leaves of *Cynoglossum officinale* L., Deckard Creek, Monroe County, September 30, 1923. I. U. 3984. Found also on the Showers' farm, August 20, 1920. I. U. 3815.

Cercospora Kellermani Bubak. On leaves of Marshmallow, *Hibiscus Moscheutos* L. In yard north-west of Bloomington, October 5, 1929. I. U. 5230. Spots very small and numerous, about 1 mm. in diameter, brown with light centers. This host was also found to be attacked by the same fungus, in the university garden, October 7, 1929. I. U. 5232. Spores 4 to 6 by 30 to 200 microns, cells very short and 15 or more in number, tapering but often with enlarged places, some very long ones enlarged at tip; conidiophores mostly much elongated, often 225 microns in length and bearing spores quite regularly from base to tip, brown. The chief reason assigned by the author of this species, for making it a new one, is that it differed from *C. malvarum* Sacc. in its many celled conidia and from *C. altheina* Sacc. in having many celled conidia and longer conidiophores.

Cercospora Rosae-indianensis n. nom. In our publication, "Some New Species of Fungi," in Ind. Acad. Sci. 38, 1928, p. 131, we failed to note that *Cercospora Rosae* (Fuck.) v. Hoehn (Syn. *Exosporium Rosae* Fuck. Symb. p. 373, 1869), was in use. It has far shorter, hyphophyllous conidiophores, and gray-green, fewer septate spores than our species. Type, I. U. 2653.

Cercospora viridula E. & E. On *Ipomoea purpurea* (L.) Roth., Sherwood's, near Bedford, Lawrence County, August 4, 1929. I. U. 5208. Spots circular, or on account of the veins, angular, 1 to 2 cm., brown, slightly paler beneath, few (in 1929; in 1927, many spots coalesced covering the leaf); conidiophores short, tapering above, pale, somewhat colored at base, tufted or a few scattered, 3 to 5 by 20 to 25 microns, some curved below tips, usually bearing a single spore; spores hyaline, few to multi-septate, straight, curved, or variously bent, some tapering in lash-like fashion, 25 to 142 by 3 to 5 microns. (Agrees fairly well, except conidiophores are almost entirely epiphyllous, a reason often used as a basis for making a new species.)

Cercospora zebrina Pass. On petioles and stems of *Medicago lupulina* L., collected from July 1, to July 11, 1929, south of Biology hall. I. U. 5085, 5100.

On *Trifolium pratense* L., same location, July 11, 1929. I. U. 5101. On *Medicago*, notes as follows: spots on leaflets rectangular, limited by veins, or triangular at tips, distinct, becoming black, 4 to 5 mm. long, yellow around the spot, later causing the entire leaflet to dry up and fall; on the stems, the spots begin as elongated, discolored areas which extend indefinitely and coalesce with others to cover the entire stem, which is killed; the conidiophores are tufted, divergent at tips, amphigenous, brown at base, colorless at tips, 25 to 60 by 3 to 4 microns, variously bent at the apex, and bearing several spores; spores hyaline, straight or curved, long-tapering. 30 to 160 by 3 to 5 microns.

Fumago vagans Pers. On *Plantago Rugelii* Dene., campus, August 5, 1929. I. U. 5214.

Ovularia obliqua (Cke.) Oud. On *Rumex crispus* L., campus, April 16, 1929, Monroe County. I. U. 5020. On *Rumex obtusifolius* L., same location, May 1, 1929. I. U. 5044.

Polythrincium Trifolii Kze. Conidial stage of *Phyllachora Trifolii* (Pers.) Fckl. This was very abundant in July and caused considerable damage to clover south of Biology hall. Specimens collected July 1, 1929. I. U. 5084.

Tubercularia vulgaris Tode. Conidial stage of *Nectria cinnabarina* (Tode.) Fr. On dying twigs of *Koelreutaria paniculata* Laxm. (*Sapindus chinensis* L.), Bloomington, Monroe County, September 18, 1929. Andrews. I. U. 5219.

INDIANA PLANT DISEASES, 1928[1]

MAX W. GARDNER and E. B. MAINS[2]

This is the tenth[3] of a series of annual summaries of the plant disease situation in the state. No claim for completeness is made.

The weather for the 1928 season, as shown in the graphs in figure 1, was characterized by a cool dry spring, very frequent and heavy rains and cool weather during June, cool dry weather in September and a warm October. Conditions were favorable for very severe epiphytotics of apple scab, rust, blotch, fire blight

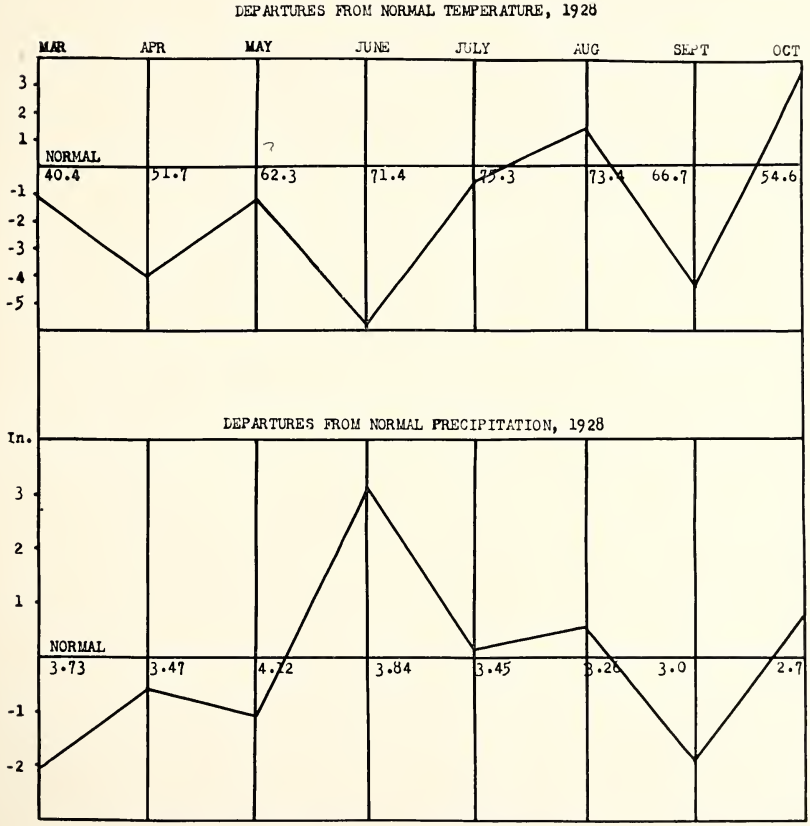

Fig. 1—Departures from normal temperature and precipitation in Indiana in 1928 based on monthly averages supplied by J. H. Armington in Climatological Data.

[1]Contribution from the Department of Botany, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

[2]The writers wish to acknowledge the coöperation of C. T. Gregory, W. E. Leer, J. F. Trost, H. E. White, M. McCown, F. P. Cullinan, H. D. Brown, Leslie Pierce, and H. F. Dietz.

[3]Proc. Ind. Acad. Sci. 1919: 135-156, 1921; 1920: 187-208, 1921; 1923: 163-211, 1924; 1924: 297-313, 1925; 1925: 237-257, 1926; 1926: 231-247, 1927; 1927: 411-426, 1928; 1928: 143-157, 1929.

and bitter rot, barley scab, sugar beet leaf spot, cabbage black leg, cantaloupe leaf blight, cherry leaf spot, Diplodia ear rot of corn, bacterial spot of peach, raspberry anthracnose, Septoria leaf sopt of tomato and wheat scab. The early summer weather was too cool to favor the Fusarium wilt diseases.

DISEASES ARRANGED ALPHABETICALLY BY HOSTS

Alfalfa. Leafspot caused by *Pseudopeziza medicaginis* was widespread. Rust (*Uromyces medicaginis*) was noted in the fall.

Apple. In central and southern Indiana the dry weather lasting until the full bloom period checked early scab infection but the almost incessant rainfall during the next six weeks caused heavy infection and made the petal-fall and two-weeks spray applications all-important in scab control. The importance of the petal-fall spray was demonstrated in tests on the Winesap and Stayman varieties near Mitchell in which the percentage of infection was greatly reduced in trees receiving both pink and petal-fall sprays as compared with those receiving only the pink spray. Among the varieties proving susceptible this season were Golden Delicious and Turley. Severe leaf infection was noted on the McIntosh variety on June 29. The margins and tips of the young leaves were killed and were covered with a greenish velvety layer of the conidia and conidiophores of the scab fungus. Although the Grimes variety is considered somewhat resistant, a grower near Laurel reports much trouble with scab on this variety.

Blotch, caused by *Phyllosticta solitaria*, was even worse than in 1927, a bad blotch year. By means of potted healthy trees placed under a badly diseased tree, Kohl found at Mitchell, that infection occurred during each of the 23 rain periods between 8 days and 10½ weeks after petal fall (May 9) and that, although none occurred during the rains of May 11 and 15, a trace occurred on May 5, four days before petal fall. Similarly he found that at Lafayette infection occurred during 22 out of the 23 rains between 4 days and 9½ weeks after petal fall (May 14). On the large green fruit of the Tulpehocken variety the smaller blotch lesions and the margins of the larger ones were conspicuously reddish or purplish in color. Infection was noted on fruit of the Golden Delicious and Early Harvest varieties, and on Grimes fruit on trees adjacent to badly cankered trees of other varieties.

Frog-eye leaf spot, caused by the black rot fungus (*Physalospora malorum*), was found very severe in July in an orchard near Mitchell on Stayman trees not receiving sprays after the pink application, while very little was present on trees receiving a petal-fall spray of lime sulphur and Bordeaux at 2, 4, and 6 weeks after petal fall. Bad leaf infection also occurred on the lower limbs of Jonathan trees. In Orange County much frog-eye infection was found surrounding rust lesions. Black rot of the fruit was very destructive in orchards near Lafayette. In October black rot pycnidia containing spores were found at Vincennes in a dead fruit spur and in a current season fire blight canker sent in from Greenfield.

Rust (*Gymnosporangium juniperi-virginianae*) was more prevalent on the foliage than has been observed during the past ten years. In July very heavy foliage infection was observed on the Jonathan, Rome, Grimes and Early Harvest varieties in unsprayed orchards. Whole trees had a conspicuous yellowish cast and many leaves were being killed by the lesions. Excellent resistance was shown by Delicious and Ben Davis trees in such orchards. Infection was not nearly as bad in sprayed orchards but much infection occurred on sprayed Rome and Jonathan trees. Fruit infection was noted on Rome, Jonathan, Stayman,

and Winesap varieties near Mitchell, and leaf infection was rather abundant on trees of the latter two varieties not receiving a petal-fall spray. Leaf infection occurred on the Golden Delicious variety.

Fire blight, caused by *Bacillus amylovorus*, was very prevalent and destructive this year, although there was not as much blossom infection as in 1926, and was reported from 16 counties. The last week in May blighting of the late bloom on Jonathan was noted at Paoli, and blight was found by McCown near Columbus, Vincennes and Pekin on Jonathan, Maiden Blush and Transparent. McCown also found infection in Jonathan fruit near Paoli early in June. Twig blight was conspicuous on Jonathan in Knox and Vanderburg counties, was found on Rome near Mitchell, and was reported by McCown on Golden Delicious.

Bitter rot, caused by *Glomerella cingulata*, was very destructive in the southern end of the state and was recorded from four commercial orchards, including the orchard in Warrick County where it has occurred for many years and where it caused nearly a total loss. In one large orchard in Knox County bitter rot caused a total loss of the Grimes crop, and in another orchard caused a heavy loss in Grimes and Jonathan and considerable loss in Rome, Ben Davis and Tulpehocken, while the Winesap variety escaped infection to a remarkable extent. A careful search in both of these orchards failed to reveal any bitter rot cankers or other original sources of infection. Bitter rot was reported on the Golden Delicious variety in Brown County.

A grower in Perry County with his orchard along the Ohio River failed to control bitter rot on Grimes and Jonathan in the low-lying part of his orchard near the river with a schedule of Bordeaux sprays which had furnished protection in previous years. The sprays were applied May 21-26, June 19-21, July 25-27, Aug. 10-12, and Aug. 25-27. The strength of copper sulphate was increased from one pound (per 50 gal.) in the first spray to two pounds in the third and three in the fourth. In a letter he states: "I think the chief difficulty lay in the time that elapsed between the second and third cover sprays. * * * Bitter rot had showed up on two trees by the middle of July, and workmen were ordered to pick these trees but failed to do so until I was applying the August 10 spray. By that time bitter rot was sweeping all Grimes and Jonathans and we had picking crews go over both five different times in an effort to check the spread; but we lost about 30 per cent of the Grimes and 50 per cent of the Jonathans. This bottom orchard lies on a bench 300 yards from the Ohio River and 40 feet above low water stage. Heavy dews and fogs keep the trees wet until the middle of the morning most days during the late summer and autumn. In my orchard on the hill top 275 feet above the river we had only a touch of bitter rot on Grimes, less than 3 per cent being affected. On these Grimes we used only the weak Bordeaux (1-3-50) in the later sprays."

Sooty blotch (*Gloeodes pomigena*) was much more severe than usual this year and was found on Rome, Winesap, Grimes, Jonathan, Stayman, and Golden Delicious. In spray tests at Lafayette, Zaring found that considerable protection was afforded by the scab sprays. This would suggest that sooty blotch infection may occur rather early in the season. Phytophthora rot was found on young Grimes fruit on the lower limbs in an orchard near Paoli by McCown on June 18.

The fruit spot and rot, caused by *Sporotrichum malorum*,[4] was found in March in stored Grimes fruit grown at Lafayette in 1928. Core-mold was noted

[4]Gardner, Max W. Sporotrichum fruit spot and surface rot of apple. Phytopath. 19: 443-452. 1929.

in Stayman fruits. Bitter pit was observed on Grimes, Stayman, and Ben Davis in Knox County.

Apricot. Twig lesions of the scab fungus (*Cladosporium carpophilum*) were observed near Bedford.

Fig. 2—Fusarium wilt of aster. Diseased plant at right, healthy plant at left.

Aster. Aster wilt caused by *Fusarium conglutinans* var. *callistephi* was much more prevalent around Lafayette than in 1927. In one planting of the Department of Botany, 52 out of 511 plants or over 10 per cent of the plants were killed by wilt (Fig. 2). It also was received from Johnson County. Mosaic, or yellows, was also of more than usual prevalence (Fig. 3). In one planting in Lafayette about 6 per cent of the plants were severely infected. Rust (*Coleosporium solidaginis*) appeared in late summer and caused considerable defoliation in some cases. Dusting with sulphur was found to be very effective in controlling this disease.[5]

[5]Mains, E. B. Control of the rusts of ornamentals by sulphur. Trans. Ind. Hort. Soc. 1928: 167-172. 1929.

Fig. 3—Effect of the virus disease, mosaic or yellows, on aster blossoms. Three diseased (at left) and one healthy blossom. The blossoms on affected plants are stunted in their development and often lopsided.

Barley. Scab caused by *Gibberella saubinetii* was very prevalent and destructive. The wet weather during June when barley was blossoming favored spread of the disease. The loss from this disease for Indiana was estimated as 20 per cent. Numerous complaints concerning difficulty in feeding infected barley were received. Considerable difference in susceptibility of varieties was noted. The hooded varieties as a group showed the most infection.[6]

Stripe, caused by *Helminthosporium gramineum*, was noted but no cases of severe infection were reported. The spot blotch, caused by *Helminthosporium sativum*, was very prevalent in the barley variety nursery at Lafayette where it caused considerable defoliation in the most susceptible varieties.

Covered smut (*Ustilago hordei*) showed about the usual prevalence and the loss from this disease was estimated to be about 1 per cent. Leaf rust, *Puccinia anomala*, was only locally abundant. Susceptible varieties at Lafayette showed 100 per cent infection. A number of varieties, especially strains of Coast, Luth, Oderbrucker, Odessa, Arequipa, Juliaca, Lynch, and Heil's Hanna, were resistant. Stem rust, *Puccinia graminis*, was less prevalent than in previous years and caused little or no loss. Ergot, caused by *Claviceps purpurea*, was noted in a few heads in the leaf rust nursery at Lafayette.

Bean. Bacterial blight, caused by *Bacterium phaseoli*, was widespread but not as serious as usual, presumably because of the low average temperatures. Mosaic was very prevalent and, together with blight, is responsible for most of the very heavy disease loss in this crop. Because of the cool weather and frequent rains, anthracnose (*Colletotrichum lindemuthianum*) was more common than usual. It was recorded from seven counties. Rust (*Uromyces appendiculatus*) was recorded from three counties in the fall. Angular leaf spot caused by *Isariopsis griseola* was found at Lafayette in July. In greenhouse inoculation tests with spore suspensions from pure cultures of *Isariopsis griseola*, 40 commercial varieties of beans were used and all proved susceptible. Some resistance was shown by the Kentucky Wonder variety. Cowpeas proved to be immune.

Beet. Leaf spot, caused by *Cercospora beticola*, occurred in gardens and in August was found very destructive in sugar beet fields in Grant County. One of these fields was on a farm where beets had never been grown before.

[6] A more detailed account of this situation is given by Mains, Vestal and Curtis elsewhere in these Proceedings. See page 101.

Blackberry. Orange rust (*Gymnoconia peckiana*) was found prevalent and conspicuous in May in plantings near Lafayette.

Blue grass. Rust (*Puccinia epiphylla*) was found very prevalent in a few lawns in West Lafayette in October. It apparently was not causing much damage.

Cabbage. Gregory reported yellows, caused by *Fusarium conglutinans*, less prevalent and black leg, caused by *Phoma lingam*, more prevalent than usual. Black rot, caused by *Bacterium campestre*, was found in Grant County in September.

Cantaloupe. Leaf blight, caused by *Macrosporium cucumerinum*, was found serious in Knox and Vanderburg counties in August. Bacterial wilt was reported from Lagrange County.

Carnation. Rust (*Uromyces caryophyllinus*) was noted in a number of greenhouses. The varieties, White Matchless, Surprise, and Harvester, were noted to be remarkably free from rust while such varieties as Super Supreme, Enchantress Supreme, Pink Enchantress, White Enchantress and Early Dawn were heavily rusted. A leaf spot of carnations caused by *Bacterium woodsii* (Fig. 4) was received from a greenhouse at Richmond where it was reported to have caused considerable loss especially in the variety White Matchless.

Fig. 4—Lesions on stem and leaves of carnation caused by *Bacterium woodsii.*

Celery. Late blight, caused by *Septoria apii*, occurred late in the season in Noble County.

Cherry. Leaf spot, caused by *Coccomyces hiemalis*, was very destructive and in Orange County was found causing defoliation as early as the middle of July. It was reported from seven counties. Powdery mildew (*Podosphaera oxycanthae*) was sent in from Pike County and was noted in Grant County in July.

Clover. Powdery mildew was widely prevalent on red clover.

Corn. Trost reported smut (*Ustilago zeae*) somewhat more prevalent than in 1927, and estimated the losses due to ear rot caused by *Gibberella saubinetii* at 1 per cent, and to the ear rot caused by *Diplodia zeae* at 10 per cent. Trost found the black bundle disease, caused by *Cephalosporium acremonium*, on barren strains of corn and attributed a 1 per cent loss to the cob rot caused by *Basisporium gallarum*. Drechsler found root infection at Lafayette caused by species of Pythium. Trost found leaf blight of sweet corn caused by *Helminthosporium turcicum* and G. M. Smith found bacterial wilt common in the Golden Bantam variety of sweet corn.

Cowpea. Bacterial spot, caused by *Bacterium vignae*, was found in experimental plots at Lafayette on June 30 and was also found in two other localities. In five small experimental plots planted with seed collected from mosaic plants in 1926, six out of 139 plants of the Arlington variety showed mosaic on June 21 and none was noted in the other four plots representing the Groit, Early Black, and Columbia varieties and the closely related species catjang, nor in plots of other varieties. On June 30, 19 of the Arlington plants showed mosaic and on August 16, 79 showed the disease, while none was found elsewhere except for two plants in a plot of the Cream Chowder variety. A rather large number of cowpea plants were exposed to natural infection, comprising in addition to the varieties mentioned above, Early Red, New Era, Early Buff, Taylor, Victor, Iron, Brabbam, Red Ripper, Black, Clay. This failure of mosaic to spread was in sharp contrast to its extensive spread in our plots in 1925 and 1926.

Cucumber. Bacterial wilt was observed in Grant County in August and in Marion County in September. Angular leaf spot, caused by *Bacterium lachrymans*, was sent in from Fulton County in July and was observed in Grant County in August. Anthracnose was found on fruits in a commercial greenhouse in June.

Currant and **Gooseberry.** Leaf spot, caused by *Mycosphaerella grossulariae*, was noted in July in Grant County.

Flowering Almond. One case of severe twig blighting of flowering almond (*Prunus glandulosa*) was found in a garden in West Lafayette. This apparently was due to the fire blight organism, *Bacillus amylovorous*, which had spread from nearby infected apple trees.

Gourd. Severe mosaic was noted in a garden in Lafayette. The infected plants were dwarfed and finally killed by the disease.

Grape. Downy mildew (*Plasmopara viticola*) was sent in from Montgomery County in August and black rot, caused by *Guignardia bidwellii*, from Washington

County in July. Specimens of anthracnose (*Sphaceloma ampelinum*) showing abundant lesions on green fruit, pedicels, and peduncles were sent in from two vineyards in Huntington County in mid-August.

Hollyhock. Leaf spots caused by *Ascochyta althaeina* and *Cercospora althaeina* caused considerable defoliation in gardens in Lafayette. Rust (*Puccinia malvacearum*) was moderatly severe. It was found that dusting with sulphur would control this rust.

Horse radish. Leaf spot, caused by *Cercospora armoraceae*, was sent in from Decatur County in August.

Iris. The diseases of Iris have been discussed in detail elsewhere.[7] The soft rot of Iris, caused by *Bacillus carotovorus*, was noted on the varieties, Blue Jay, Nibelungen, Quaker Lady, Queen Caterina and Purple King, at Lafayette. One of the English irises, Rosa Bonheur, was completely destroyed and the species, *Iris laevigata*, *I. spuria*, *I. halophila* and *I. setosa*, showed rotting following borer infestation. Sclerotial rot caused by *Sclerotium delphinii* was severe on the varieties Lent A. Williamson, Blue Boy, Dalila and Pallida Dalmatica. Leaf spot caused by *Didymellina iridis* was especially prevalent. The varieties, Florentina Alba, Monsignor, Fairy, Ballerine, Queen Caterina Queen Alexandra,

Fig. 5—*Lilium tenuifolium* infected with *Phytophthora cactorum*. Infection occurred near the surface of the ground resulting in the collapse of the infected portion and breaking over of the plant.

[7]Mains, E. B. Observations concerning diseases of iris and tulips. Proc. Ind. Acad. Sci. **38** (1928): 93-102. 1929.

Quaker Lady, and Violacea grandiflora, were outstanding for restricted development of the disease. Rust (*Puccinia iridis*) was noted severe on *Iris halophila, I. xiphioides, I. missouriensis,* and *I. setosa* while none was noted on a number of other species nor on the varieties of bearded iris.

Lettuce. In a patch of head lettuce grown with overhead irrigation near Lafayette, drop caused by *Sclerotinia libertiana* was very destructive in June and downy mildew (*Bremia lactucae*) was very abundant.

Lily. A stalk blight of coral lily, *Lilium tenuifolium,* was found in a garden in West Lafayette in May, 1928. Infection apparently occurred at or below the ground level, the disease spreading upward and causing the stalks to become soft and fall over (Fig. 5). The fungus was isolated and sent to Dr. Charles Drechsler who identified it as *Phytophthora cactorum.*

Lima bean. Bacterial spot, caused by *Bacterium vignae,* was sent in from Dearborn County in June and was observed near Vincennes in July.

Narcissus. Fusarium bulb rot (Fig. 6) was found by Dietz in bulbs shipped into Indiana from Ohio.

Oats. The loose smut of oats caused by *Ustilago avenae* occurred to some extent in most fields. The loss from this disease was estimated at 3 per cent for 1928. Stem rust (*Puccinia graminis*) was less prevalent than in previous years and caused but little loss. On July 14, Leer found stem rust appearing on oats. The heaviest development was noted in the western part of the state between Terre Haute and Rensselaer and eastward to Wabash, Marion and Anderson. Crown rust (*Puccinia coronata*) was less prevalent than in previous seasons but was usually present to some extent in most fields. The loss for the state was estimated at 1 per cent.

The scab of oats, caused by *Gibberella saubinetii,* was unusually severe. While it was not as uniformly prevalent on oats as on barley and wheat, it

Fig. 6—Fusarium bulb rot of narcissus. White mycelium of the fungus is conspicuous between the darkened and rotted scales and in the cavity at the center of the bulb.

was very severe locally. A number of farmers in the vicinity of Liberty, Union County, were unable to feed their oats to hogs, horses and mules on account of scab. One man alone had 3,200 bushels which could not be fed. A somewhat similar situation occurred in Clinton County. The loss from this disease was estimated at 3 per cent.

Halo blight, caused by *Bacterium coronafaciens*, was found to some extent throughout the state, the most serious case being reported from a farm near Mulberry, Clinton County. A leaf spot apparently caused by *Helminthosporium avenae* was found causing considerable defoliation in variety plots on the University farm east of Lafayette.

Pansy. A leaf spot of pansy apparently caused by *Cercospora violae* was noted in several gardens in West Lafayette. This disease became prevalent during hot weather in July and caused severe defoliation.

Pea. Fusarium wilt was serious near Tipton in June. Dr. M. B. Linford, specialist in pea diseases, found Ascochyta foot rot prevalent in fields about Plymouth, a new territory for this crop, and near Rochester, a region where peas have been grown for a long period. Near Rochester he also found Fusarium wilt and the root rot caused by *Aphanomyces euteiches*.

Peach. Leaf curl, caused by *Exoascus deformans*, was prevalent in unsprayed trees but not as serious in commercial orchards as in 1927, perhaps because it was a late spring and growers were able to apply the dormant spray before the buds started to swell. In experimental plots at Vincennes, Pierce obtained excellent control with a Bordeaux-oil spray on November 26 preceding, and no control with oil alone or with oil plus copper sulphate. Scab, caused by *Cladosporium carpophilum*, was reported worse than usual this year. Fruit infection was observed in Knox, Marion, and Lawrence counties.

Bacterial spot, caused by *Bacterium pruni*, was observed in Knox, Orange, Lawrence, and Vanderburg counties, and was even more destructive than in 1927, causing very severe fruit infection and early defoliation. Furthermore numerous twig lesions were formed on the current season growth differing quite distinctly from the leaf scar arsenic cankers in location and shape. The bacterial lesions were more elongated and more irregular in shape and if located at a leaf scar usually extended out from one side of the scar rather than being centered about it. When these cankers were shaved off, cut up in a drop of water on a slide, and examined microscopically, a vigorous oozing of masses of bacteria was easily observed along the cut edges. These lesions were found in Knox county in abundance as early as July 16. Pierce[8] and Roberts obtained a good control of this disease at Vincennes with a zinc sulphate-lime spray. On July 16, two instances were observed in which the disease was much worse on the foliage of young plantings than in old orchards immediately adjacent. In one orchard it was observed that the Krummel variety seemed somewhat resistant to leaf infection as compared with the Hale variety.

Apothecia of the brown rot fungus (*Sclerotinia fructicola*) were found by Pierce at Vincennes under a seedling tree on April 3, where none had been visible the previous day. By April 6, the varieties Hale, Elberta, and Hiley were in full bloom and Pierce counted 19 clusters of apothecia under the

[8]Pierce, Leslie. Control of peach bacterial spot. Trans. Ind. Hort. Soc. 1928: 120-124. 1929.

seedling tree and ascertained that the ascospores were ready to germinate. On May 18, after a prolonged rain period, Pierce found the fungus sporulating profusely on blighted leaves and blossoms and on small twigs where blighted blossoms had been attached. On June 5, he observed fruit infection. However, in spite of these abundant sources of infection, Pierce found very little brown rot when the crop was harvested.

Dr. L. M. Hutchins, specialist in peach virus diseases, visited a number of the orchards in the Vincennes region and found no peach yellows, rosette, little peach or phony disease.

Pear. Fire blight, caused by *Bacillus amylovorus*, was very destructive this season and was reported from seven counties. The fire blight in the young Bartlett orchard in Putnam County mentioned in our last year's report was cut out early this spring and although this was a bad blight season, only a very few limbs became infected. In a well isolated orchard such as this, it may be possible to control the disease.

Plum. Black knot, caused by *Plowrightia morbosa*, on the Blue Damson variety was sent in from Hendricks County on April 3 and the perithecia contained ascospores which apparently were mature. Specimens were also received from Brown and Marion counties. Fruits of the Abundance variety bearing lesions of bacterial spot, caused by *Bacterium pruni*, were sent in from Warsaw on July 21.

Potato. Black leg, caused by *Bacillus phytophthorus*, occurred in the early crop in Orange County.

Quince. Fire blight, caused by *Bacillus amylovorus*, was sent in from Marion County.

Radish. Black root, caused by *Aphanomyces raphani*, was sent in from Hendricks County on July 3. A new bacterial spot disease, of which the causal organism closely resembles that of tomato bacterial spot,[9] has been found near Lafayette and in Grant County. Other hosts found susceptible in inoculation tests include cabbage, brussels sprouts, kale, cauliflower, mustard, turnip, tomato, pepper and tobacco. Transmission with radish seed was demonstrated. It seems fairly certain that the radish seed pod lesions illustrated in our 1925 report (p. 241) were attributable to this disease.

Raspberry. Anthracnose (*Plectodiscella veneta*) lesions were observed near Lafayette on new canes on May 25. In midsummer the disease was abundant on the upper parts of the plants including pedicels and in October very late infection was evidenced by the abundance of small lesions on the tips of the canes. Leaf spot, caused by *Mycosphaerella rubina*, was observed in Grant County in July and August. Orange rust (*Gymnoconia interstitialis*) was observed in May on a few red raspberries in a row adjacent to badly infected blackberries. Crown gall, caused by *Bacterium tumefaciens*, was sent in from Parke County. Conspicuous mosaic was found abundant in a plant of the Cumberland variety at Lafayette on May 21 and was also noted in red varieties. Leaf curl was observed on the Cumberland and Plum Farmer varieties at Lafayette on May 25.

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[9] White, Harold E. and Gardner, M. W. Bacterial spot of radish and turnip. Abs. in Phytopathology 19: 97. 1929.

The red variety, St. Regis, has shown marked freedom from virus diseases in a commercial planting near Lafayette.

Rose. Powdery mildew (*Sphaerotheca pannosa*) was noted on the variety Dorothy Perkins and was responsible for defoliation and blasting of flower buds. Black spot, caused by *Diplocarpon rosae*, was fairly common and caused severe defoliation in a few cases.

Rye. Scab, caused by *Gibberella saubinetii*, was the most severe disease of rye in Indiana in 1928. While this disease was not as prevalent on rye as on barley and wheat it caused a loss estimated at 5 per cent for the state. Ergot, caused by *Claviceps purpurea*, was found to a varying extent in rye fields and a loss in yield of 1 per cent was estimated for the state. Anthracnose, caused by *Colletotrichum cereale*, was less severe than in previous years.

The leaf rust of rye (*Puccinia dispersa*) was less severe than in previous years. The severe winter of 1927-1928 greatly reduced the amount of rust which overwintered and the rust was not generally prevalent until late in the season. On June 30 Leer reported leaf rust in Tippecanoe, Clinton, Hamilton, Jasper, Lake, Howard, Wabash, Miami, Huntington, Allen, and Dekalb counties and on July 7 in Boone, Marion, Henry, and Rush counties. Stem rust (*Puccinia graminis*) was less prevalent than in previous years and caused little or no loss.

Snapdragon. Rust (*Puccinia antirrhini*) was noted in several gardens in West Lafayette. In variety tests of the Department of Botany, susceptible varieties such as Nelrose, Gotelind, and Maralda were so severely rusted that most of the plants were dead by the end of the summer. Selections are being developed which are very resistant. Dusting with sulphur has controlled this disease (l.c.[5]).

Soybean. Downy mildew (*Peronospora manshurica*) was found for the first time. It was first noted on Aug. 14 in the Manchu variety at Lafayette, and was later noted in Grant and Knox counties. Apparently the disease was only of

Fig. 7—Yellowish lesions of downy mildew (*Peronospora manshurica*) on soybean leaves (var. Manchu). This disease was found for the first time in Indiana this year.

slight economic importance. Leaf spot, caused by *Septoria glycines*, was sent in from Jasper County. Bacterial spot, caused by *Bacterium glycineum*, was noted at Lafayette and in Knox County. Mosaic was observed in the Manchu variety at Lafayette.

Spinach. Downy mildew (*Peronospora effusa*) was found rather destructive in Grant County on May 22 in a canning crop field in which spinach was grown the previous year.

Strawberry. Leaf spot, caused by *Mycosphaerella fragariae*, was observed in Tippecanoe and Grant counties.

Sweet potato. Gregory reported stem rot, caused by *Fusarium batatatis*, prevalent and destructive in Knox County and black rot, caused by *Sphaeronema fimbriatum*, in Sullivan County.

Tomato. Leaf spot, caused by *Septoria lycopersici*, was extremely widespread and destructive in the canning crop because of the frequent rains. The disease was recorded from 14 counties. The disease was observed in plant beds in Orange and Grant counties and was found severe in certain fields as early as June. Additional evidence of its introduction with southern-grown plants was obtained. As a result of a field survey involving 1991 acres made by Mr. L. E. Breithaupt and the canning companies yield records on this acreage, Prof. H. D. Brown estimated the total loss in the state caused by early infection of leaf spot to be over $100,000 this year. In dusting tests[10] in Grant County, it was found that poor control was obtained with as few as three applications of copper lime.

Early blight, caused by *Alternaria solani*, was found prevalent in plant beds in Grant County and became generally prevalent in the field. The collar rot effect of this disease was observed in August, and the fruit spot and stem-end rot in September. In general the foliage injury by this disease appears to be worse on the poorer soils. Fusarium wilt was not serious, probably because of the low average temperatures. It was sent in from Jackson County in July and was found in Grant County in August.

Mosaic was much less prevalent than usual. A few plants representing peculiar types of what may be virus diseases were noted in Grant County in August. In one type the plants were stunted and non-fruitful and the leaflets were narrow, erect, stiff, and slightly yellowish. In another type the plants were stunted and barren with curled petioles and necrotic surface lesions near the base of each petiole. Samson was not able to transmit these abnormalities by juice inoculation.

Leaf mold (*Cladosporium fulvum*) was very serious in greenhouses. Anthracnose (*Gloeosporium phomoides*) was found on the late set of fruits in Grant County. Buckeye rot, caused by *Phytophthora parasitica*, was noted in a greenhouse crop.

Bacterial spot, caused by *Bacterium vesicatorium*, was rather prevalent on the early set of fruit. A few cases of bacterial canker, caused by *Aplanobacter michiganense*, were found in Rush and Marion counties in southern-grown plants. In a greenhouse crop, serious injury resulted from cyanide fumigation of plants previously dusted with copper lime dust.

[10]Gardner, Max W., Samson, R. W., and Cochran, L. C. Dusting tests for the control of tomato diseases, 1927 and 1928. Proc. Ind. State Veg. Growers Assoc. 1929: 11-25. 1929.

Tulip. The Botrytis blight or fire disease caused by *Botrytis tulipae* was very prevalent (l.c.[7]). It was favored by wet weather and tulips in some gardens in Lafayette showed severe infection, especially when planted in partially shaded places. Sclerotia of this fungus were noted on bulbs shipped in from Holland.

Turnip. An undescribed bacterial spot disease was found on turnips in Grant County on July 26. The organism was also found to be the cause of a spot disease of radish, previously described. Powdery mildew (*Erysiphe polygoni*) was observed in Grant County in September.

Wheat. The severe winter of 1927-1928 resulted in a greatly reduced acreage of winter wheat, the acreage being 900,000 as compared with 1,782,000 in 1927[11]. As a result considerable winter wheat was replaced by other crops.

The wet weather during and following the blossoming of wheat in late May and June was very favorable to the development of scab caused by *Gibberella saubinetii*. The spread of the fungus from initial infections from ascospores was rapid and in susceptible varieties often the whole head was filled with the fungus. Conditions apparently were especially favorable for perithecial formation and before harvest the heads of many varieties were covered with the black perithecia. There were noticeable differences in the susceptibility of varieties especially in spring wheats. The varieties Norka, Progress, Resaca, and especially Illinois No. 1 were outstanding for resistance[12]. Illinois No. 1 showed only 17-19 per cent of kernels infected while Federation in nearby rows had 96 per cent of infected kernels. The loss in yield for the state was estimated at 15 per cent.

Loose smut of wheat (*Ustilago tritici*) was less prevalent than in 1927. The severe winter killing probably was a factor in reducing the proportion of smutted plants since Tapke[13] and others have shown that infected plants are more subject to winterkilling. It could be found to some extent in most fields and the loss was estimated at 0.5 per cent. Bunt, due to *Tilletia laevis*, was also much less prevalent than in 1927, the loss being estimated at 0.5 per cent.

Leaf rust, caused by *Puccinia triticina*, was also much less prevalent than in previous years. The winterkilling of wheat greatly reduced the overwintering of the fungus in the wheat so that the numbers of centers of infection were greatly reduced and the rust developed slowly. Leaf rust was noted by K. D. Doak in southern Indiana on June 15, the incidence varying from 30 to 100 per cent. The wheat was in the milk to soft dough stages. Only a trace was noted by Leer in northern Indiana on June 30, when wheat was in the milk stage. At Lafayette on July 5 only a moderate infection was present except upon very susceptible varieties such as Little Club which showed 100 per cent infection. Leer reported only a moderate infection in northern Indiana at the time of harvest. The loss from this disease was estimated at 1 per cent.

Stem rust (*Puccinia graminis*) was less prevalent than in 1927. Leer found an occasional infected plant in Allen and Wabash counties on June 27. Late plants in fields thinned out by winterkilling and replanted with oats and other crops in some cases showed considerable infection in July. At harvest Leer reported only a trace in most parts of the state, the most occurring in the central third of the state.

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[11]Borum, C. J. and Justin, M. M. Annual Crop Summary for 1928. Ind. Crops and Livestock No. **39**. 1928.

[12]Dickson, J. G., E. B. Mains and Helen Johann. Progress report on cereal scab development during the season of 1928. Phytopath. **19**:108. 1929.

[13]Tapke, V. F. Influence of varietal resistance, sap acidity, and certain environmental factors on the occurrence of loose smut in wheat. Jour. Agr. Research **39**:313-339. 1929.

The speckled leaf blotch of wheat caused by *Septoria tritici* was more prevalent than in previous years and caused considerable defoliation of susceptible varieties. Marquillo was especially susceptible and Illinois No. 1 was rather resistant. A slight amount of ergot, caused by *Claviceps purpurea*, was noted in the leaf rust nursery at Lafayette. A variety of Chinese wheat, C. I. 6223, showed the most ergot infection.

Miscellaneous. The following diseases or parasitic fungi were found, all near Lafayette unless otherwise specified: Leaf spot on bittersweet (*Celastris scandens*) caused by *Ramularia celastri;* rust (*Kuehneola uredinis*) on wild blackberry; *Piricularia grisea* on bottle grass (*Setaria viridis*) (by Dr. C. Drechsler); *Microsphaera alni* on coral berry and honeysuckle; *Epichloe typhina* on grass from Jennings County, June 13; fire blight, caused by *Bacillus amylovorus*, on English hawthorn (*Crataegus oxycanthae*) in Marion County; bacterial leaf spot, caused by *Bacterium malvacearum*, on *Morus alba* var. *pendula; Albugo ipomoeapanduranae* on wild morning glory; *Phytophthora paeoniae* on peony (Tippecanoe and Knox counties); leaf spot, caused by *Cercospora rhoina*, on *Rhus typhina; Sphaerotheca humuli* on *Rhus canadensis;* sycamore anthracnose; rust (*Melampsora humboldtiana*) on basket willow (Putnam County).

During the wet weather of May and June a serious damping off of seedlings and blighting of a number of ornamentals occurred in a garden in West Lafayette. Parts of plants, such as the leaves, in contact with the ground were invaded and infection spread from these to the rest of the plant often causing death. The disease apparently was caused by a species of Rhizoctonia. Calendula, California Poppy, Canterbury Bells, Peachleaf Campanula, Forget-me-not, Foxglove and *Anchusa capensis* were all severely infected.

SUMMARY

The diseases found to be of outstanding economic importance in 1928 were apple scab, blotch, rust, and bitter rot, barley scab, beet leaf spot, cantaloupe leaf blight, cherry leaf spot, oat scab, peach bacterial spot, raspberry anthracnose, rye scab, tomato leaf spot (Septoria), and wheat scab.

Parasitic organisms or diseases not previously reported present in the state, at least in this series, were *Bacterium woodsii* on carnation, Basisporium cob rot of corn, *Phytophthora cactorum* on lily, Fusarium bulb rot of narcissus, bacterial spot of radish and turnip, *Peronospora manshurica* on soybean, *Aplanobacter michiganense* on tomato, and *Bacillus amylovorus* on flowering almond and *Crataegus oxycanthae.*

Observations of more than passing interest were the susceptibility of the Golden Delicious, a new variety of apple, to scab, blotch, rust, fire blight, and bitter rot, greater severity of apple bitter rot in valley as compared with higher part of an orchard, evidence for early infection by apple sooty blotch, deleterious effect of scab on feeding qualities of barley and oats, abundance of twig lesions of peach bacterial spot, presence of Plowrightia ascospores in plum black knots on April 3, late fall infection of raspberry anthracnose and freedom of St. Regis variety from virus diseases, scab resistance of certain wheat varieties, and severity of Rhizoctona damping-off of seedlings of ornamentals.

SCAB OF SMALL GRAINS AND FEEDING TROUBLE IN INDIANA IN 1928[1]

E. B. Mains, C. M. Vestal, and P. B. Curtis, Purdue University

Cause. In Indiana, the disease of cereals known as scab[2] is chiefly caused by the fungus, *Gibberella saubinetii* (Mont.) Sacc. (*Fusarium graminearum* Schw.). On small grains, it is most serious as a head blight. This first becomes evident by the loss of green color of some of the spikelets. Such spikelets turn yellow (fig. 1) and later brown, followed by the development of a reddish mold. If wet, humid weather prevails, the fungus spreads in the head causing the newly infected portion also to turn yellow, then brown with accompanying development of the reddish mold.

Fig. 1—Effect of scab on wheat. Four heads to the left from Marquis showing different degrees of infection before maturity as indicated by prevalence of light colored spikelets. Head to the right from Little Club showing perithecia development at maturity.

[1]Contribution from the Departments of Botany, Animal Husbandry and State Chemistry Agricultural Experiment Station, Purdue University.

[2]James G. Dickson and E. B. Mains. Scab of Wheat and Barley and Its Control. U. S, Dept. Agr. Farmers Bul. 1599. 17 p. 1929.

The effect on the grain depends upon the stage at which infection occurs. Early infection just following blossoming often completely prevents the development of the kernel, leaving nothing but the glumes covered by the mycelium of the fungus. Kernels infected later are penetrated and enveloped by the fungus and their development stopped. Such kernels are overgrown by a reddish fungus growth and are fragile and easily reduced to a powdery mass. Still later infection may result principally in more or less shrivelling and various degrees of moldy development.

Some seasons, as in 1928, another stage of the fungus develops on the heads before harvest. This is the perithecial stage which appears as small black bodies scattered over the infected heads (fig. 1). This stage also usually develops in the spring on plant rubbish such as straw, corn stalks, etc.

The fungus may also cause a seedling blight. This may develop from scabbed seed or when grain is planted in infected soil. Under such conditions the seedlings are attacked and frequently killed even before emergence. The fungus may also spread to adjacent plants, causing a yellowing and often death, resulting in thin stands. Seedling blight of wheat is favored by high temperatures at planting time.[3] [4]

As mentioned above the fungus lives over winter in rubbish such as infected straw and corn stalks.[5] [6] [7] [8] The perithecial stage, which is developed on such material discharges, its ascospores about the time that the small grains are blossoming. If weather conditions are favorable the heads become infected, with resulting spread and loss in yield and quality.

Situation in 1928. The winter of 1927-1928 was unusually severe for winter wheat in Indiana. In summarizing the situation, Borum and Justin[9] point out that twice in December 1927, following rain storms, temperatures dropped in a short time as much as 50 degrees to points near zero. Snow cover was scanty throughout the winter and the loss in winter wheat acreage was the greatest in the history of the state. It was estimated that 1,500,000 acres of seeded crops were lost. This resulted in the planting of such land with other crops. Barley was one of the crops used and as a result the acreage increased from 35,000 in 1927 to 94,000 in 1928.

The prolonged wet weather in May and June, during and following the blossoming of small grains, was very favorable for the development of scab and as a result reached epidemic proportions such as had not been attained since 1919. Although wheat was probably as severely infected as in 1919, the greatly reduced acreage was responsible for less loss than in 1919. Barley, however, was much more severely infected and the increased acreage made the disease much more of a factor in this crop than in 1919. It is estimated that in Indiana, scab caused a reduction in yield 15% in wheat, 20% in barley, and 3% in oats.

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[3]James G. Dickson and James R. Holbert. The Relation of Temperature to the Development of Disease in Plants. American Naturalist **62**:311-333. 1928.

[4]Jean MacInnes and Raymond Logelman. Wheat Scab in Minnesota. Univ. Minn. Tech. Bul. 18: 32 p. 1923.

[5]G. N. Hoffer, A. G. Johnson and D. Atanasoff. Corn-Rootrot and Wheat Scab. Jour. Agr. Research **14**:611-612. 1918.

[6]J. R. Holbert, J. F. Trost, and G. N. Hoffer. Wheat Scabs as Affected by Systems of Rotation. Phytopathology **9**:45-47. 1919.

[7]D. Atanasoff. Fusarium-Blight (Scab) of Wheat and Other Cereals. Jour. Agr. Research **20**:1-32. 1920.

[8]B. Koehler, J. G. Dickson and J. R. Holbert. Wheat Scab and Corn Rootrot caused by Gibberella Saubinetii in Relation to Crop Successions. Jour. Agr. Research. **27**:861-879. 1924.

[9]C. J. Borum and M. M. Justin. Crop Summary for Indiana, 1928. Indiana Crops and Livestock No. 39:182. 1928.

Feeding trouble. Not only was there a reduction in yield of these cereals but shortly following harvest numerous reports were received from farmers in different parts of the state concerning trouble feeding such grain. These reports increased in number as the season advanced.

In most cases barley was causing the trouble. Fewer reports were received of trouble with oats and only a few cases of trouble with wheat screenings were reported. Most farmers were attempting to use their barley for hog feed and generally they complained that hogs refused to eat the feed or ate very little. In some cases it was stated that hogs were made sick, vomiting after eating the feed apparently after having been forced to it by starvation. In a few cases death of hogs following feeding was reported. A few farmers reported attempting to feed scabby grain to horses and mules. Both refused to eat such grain.

Distribution of the trouble. Over 89 reports of trouble feeding barley were received from the following counties: Adams, several; Allen, 15; Benton, 1; Blackford, 1; Carroll, 6; Cass, 7; Clinton, many; Dekalb, several; Elkhart, 1; Fountain, several; Grant, 2; Hamilton, 4; Hancock, 1; Henry, many; Howard, 1; Huntington, many; Kosciusko, 3; Lake, 1; Laporte, several; Madison, 6; Miami, 2; Monroe, several; Montgomery, 2; Newton, several; Owen, 1; Parke, several; Porter, 3; Pulaski, 4; Randolph, 2; Rush, 1; St. Joseph, 1; Sullivan, 1; Tippecanoe, several; Tipton, 2; Vermillion, 1; Warren, 1; Washington, 1; Wells, 1; White, 2; Whitley, 4. These represented only a portion of the farmers having trouble. In several cases county agents reported the trouble as "general," "many," etc. and several farmers stated that all their neighbors were also having trouble.

In Carroll County, one farmer had 2,000 bushels which his hogs refused to eat but no difficulty was experienced with cattle. In Howard County a farmer reported having 1,000 bushels which hogs refused even when only making up 1-3 of a mixture with other feed. A number of farmers reported having 100 to 800 bushels of barley which they were unable to feed hogs.

Reports of trouble in feeding oats were received from Clinton and Union counties. County Agent V. J. Mann of Clinton County reported that one farmer had trouble feeding horses and mules oats which cows ate. County Agent L. J. Reynolds reported that a group of farmers around Liberty, Union County, were having trouble feeding their oats to hogs. One of these farmers had 3,200 bushesl which he was not able to feed hogs or horses.

A number of samples of the barley and oats causing trouble, were received. In all cases there was a large proportion of kernels infected with scab. These contained from 16 to 65% of infected kernels. Several farmers reported being able to feed barley from one field and not from another. In one case samples were received and the barley causing feeding trouble contained 65% infected kernels and that successfully fed had 9%.

That this trouble was not confined to Indiana was soon evident from reports from neighboring states, especially Ohio, Illinois, Wisconsin and Iowa. Similar trouble with barley shipped from United States was also experienced abroad, especially in Germany.[10] [11] [12] [13]

[10]Stang. Ungeklarte Schadlichkeit amerikanischer Gerste. Deutsche Landw. Presse **39**:564 1928. Abstract. Rev. App. Myc. **8**:98. 1929.

[11]Opperman and Doenecke. Futterungsversuche mit amerikanischer Giftgerste. Deutsche tierarztl. Wochenschr. **37**:165-167. 1929. Abstract Rev. App. Myc. **8**:440. 1929.

[12]H. Miessner and G. Schoop. Uber den Pilzbefall amerikanischer 'Giftgerste' Deutschetierarztl. Wochenschr. **37**:167-170. 1929. Abstract Rev. Appl. Myc. **8**:440. 1929.

[13]Die Ursache der Giftigkeit der amerikanischen Gerste. Mitt. Gesellsch. Vorratsschutz **4**:66-67. 1928. Abstract Rev. App. Myc. **8**:439. 1929.

A search of the literature did not reveal any reference to previous trouble in the United States. An examination of the files of the Department of Animal Husbandry, however, resulted in finding several letters from farmers in 1919 complaining of a similar trouble in feeding barley. The year 1919 was also a severe scab year. Dr. J. G. Dickson in answer to inquiries concerning the situation stated that some trouble had also been experienced in Wisconsin in 1919. Closely related species of Fusarium have been credited with toxic action on man and other animals[14 15 16 17] in Russia causing dizziness, etc.

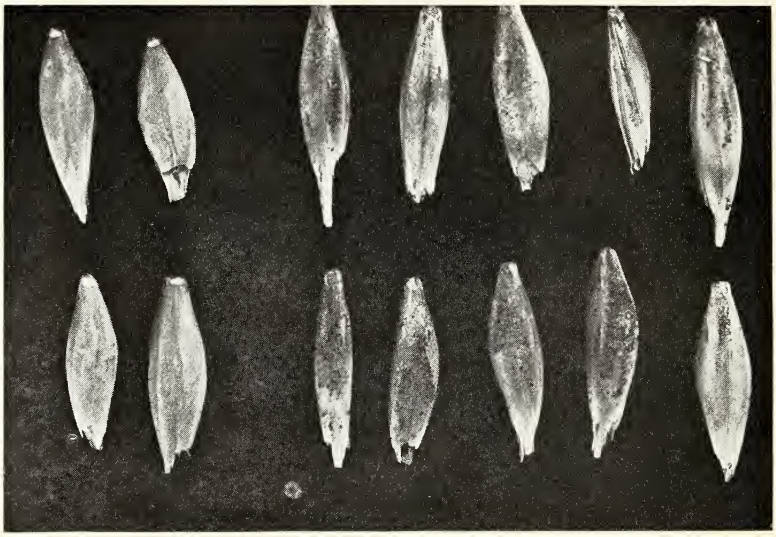

Fig. 2—Scab on Barley. Ten kernels to the left severely scabbed as indicated by light colored mycelium and conidia and black perithecia. Four kernels to the right free from the fungus.

Experiments with Hogs. The widespread trouble in feeding and the number of inquiries resulting made it desirable to obtain more information concerning the situation. Consequently Director J. H. Skinner called a meeting of members of the departments of Chemistry, Animal Husbandry, Dairying, Veterinary, Soils and Crops, Poultry and Botany of the Purdue Agricultural Experiment Station and arrangements were made to study the situation under the chairmanship of Dr. H. R. Kraybill. In these studies the writers have been fortunate in having the advice of Dr. J. G. Dickson of the Department of Plant Pathology of the University of Wisconsin and of the Office of Cereal Crops and Diseases, United States Department of Agriculture, who has made a special study of this disease for a number of years and who freely furnished information concerning his own extensive feeding experiments.

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[14]J. Eriksson. Fungoid Diseases of Agricultural Plants. p. 153-154.
[15]A. Pomaskii. Regarding the Changes in Chemical Composition of Rye Resulting from the Activity of Certain Fusarium Forms. Abstract. Exp. Sta. Record **35**:845. 1916.
[16]A. Pomaskii. Changes in the Chemical Composition of Rye under Influence of Species of Fusarium. Abstract Exp. Sta. Record **36**:635. 1917.
[17]N. A. Naumov. Intoxicating Bread. Abstract Exp. Sta. Record **36**:747. 1917.

Experiment 1. A series of feeding tests were conducted to verify the reports which had been received and to determine whether the objection could be overcome. In the first experiment, six thrifty shoats having a total weight of 695 pounds were changed from a full feed of corn and tankage on a clover pasture to a full feed of dry ground scabby barley and tankage in a dry lot. The barley (lot A) used was a mixture of several varieties of the 1928 crop from the Soils and Crops Department and a count showed 58% of the kernels were more or less scabbed. (Fig. 2). Two of the pigs were fed this barley without modification. For two of the pigs, the barley was cleaned removing the lighter kernels with the idea that this might remove most of the objectional material. About 35% of scabbed kernels still remained. The other two pigs were feed the screenings which consisted largely of scabby kernels.

None of the pigs ate much. At the end of the first three days their total weight was 611 lbs., a loss of 84 lbs. The ration of each lot of two pigs was changed to include one-half ground corn. This stimulated the appetite of all the pigs temporarily and in the next two days the total weight of the six pigs increased from 611 to 626 lbs. However, during the next four days the two pigs fed the mixture of uncleaned barley and corn just maintained their weight, the two fed cleaned barley and corn lost 1 lb. and the two with screenings and corn lost 2 lbs., the total weight of the six being 608 lbs.

The preceding rations were then modified by adding water to the feed at feeding time. This also temporarily stimulated the appetites of the pigs and the weight of the six increased from 608 to 621 lbs. in the next two days. However, at the end of six days the two having uncleaned barley had lost 3 lbs., the two with screened barley had gained 2 lbs. and the two with screenings had maintained their weight, the total weight of the six pigs falling back to 607 lbs. At this time some of the pigs were so weak and emaciated that they were unable to walk with a steady gait.

The rations were then again changed to one-third ground scabby barley, one-third ground oats, one-third ground corn plus tankage for the pigs with the uncleaned and cleaned barley. The pigs which had been fed screenings were changed to a ration of two-thirds ground corn, one-third ground oats plus tankage. These changes stimulated the appetites in each case. At the end of the first three days, the two pigs having one-third uncleaned scabby barley had gained 12 lbs., the two with one-third cleaned scabby barley, 17 lbs., and two without barley had also gained 17 lbs. These rations were continued for 14 more days. At the end of this time, the two pigs fed one-third uncleaned scabby barley had lost 5 lbs. The two with one-third cleaned scabby barley had gained 14 lbs. and the two without barley had gained 27 lbs.

During this experiment, the feeds were kept fresh and were fed according to the appetites of the pigs. The results agreed with most of the reports which had been received. The pigs were not sick. They apparently found the feed disagreeable and reduced their consumption of it. A change in the method of feeding stimulated consumption temporarily after which apparently the effect of the scabby barley again resulted in reduced consumption. Cleaning the barley did not sufficiently reduce the amount of scabby grain of the lot used. It was necessary to reduce this to less than one-third of the ration with other grain before it could be fed with any success. This would indicate that scabbed kernels should be reduced to 10% or less but even this probably depends upon the degree to which such kernels are invaded.

Experiment 2. In connection with the preceding experiment, it was suggested that the sudden change from corn, tankage and clover pasturage to barley might have been responsible for the refusal of the new ration. Consequently another feeding experiment was started September 15, 1928, in which six shoats with a total weight of 723 lbs. were changed from a full feed of corn, tankage and clover pasturage to a ground feed consisting of 9 parts of barley and one part of tankage in a dry lot. The barley used was from the 1927 crop and was practically free from scab. The six pigs ate this ration readily but the change in feed resulted in a temporary loss in weight, the total weight dropping from 723 to 718 lbs., a loss of 5 lbs. in the first two days.

After the first two days, they started to gain in weight, the next day weighing 719 lbs. Three days later (after Sept. 17), they weighed 732 lbs., gaining 13 lbs.; after 5 days, 738 lbs., gaining 20 lbs.; after 8 days, 754 lbs., gaining 36 lbs.; after 11 days 808 lbs., gaining 89 lbs.; after 14 days 825 lbs., gaining 107 lbs. The average daily gain per pig during the period from Sept. 17 to Oct. 1 was 1.27 lbs. The feed was eaten with a relish and all the animals were thrifty. The change to barley had only a slight two day check upon the development of the animals.

It was found possible to divide this lot of six pigs into three groups, each group of two pigs weighing 275 lbs., Group A containing pigs weighing 131 and 144 lbs.; group B, pigs weighing 136 and 139 lbs., and group C, pigs weighing 133 and 142 lbs. Group A was continued on the ration of ground, 1927, scab-free barley and tankage. Group B was changed to a ration consisting of 9 parts of ground, scabby barley and 1 part tankage. A different lot of scabby barley from that used in experiment 1 was fed. This barley (lot B) was obtained from a farmer of Tippecanoe County who had had trouble feeding it to hogs. It contained 51% of kernels showing more or less scab infection. Since some reports had been received that scabby barley had been successfully fed when blackstrap molasses was added, group C was fed 9 parts of ground, scabby barley (B), 1 part tankage and blackstrap molasses diluted with 10 parts of water was poured over the rations at feeding time.

Scabby barley with molasses was fed to group C for 24 days during which time their weight dropped from 275 to 235 lbs., a loss of 40 lbs. Group B fed scabby barley without molasses, dropped from 275 to 260 lbs., a loss of 15 lbs. during the same time. Group A fed scab-free barley increased from 275 to 347 lbs., an increase of 72 lbs.

With the idea that cooking might destroy the objectional principal of the scabby barley, the molasses was left out of the ration of group C and the feed was cooked. This ration was fed for 9 days with a resulting increase from 235 to 241 lbs., an increase of 6 lbs. However, group B on the same ration not cooked also increased from 260 to 271 lbs., an increase of 11 lbs. Group A showed a considerably greater increase, going from 347 to 380 lbs., an increase of 33 lbs.

Group C was then changed to a cooked ration of 9 parts whole scabby barley and 1 part tankage. There was a temporary increase in weight since they increased from 241 to 250 lbs. during the first three days. However, at the end of twelve days, they weighed 240 lbs., a loss of 1 lb. Group B on ground, uncooked scabby barley remained at practically the same weight throughout this period, only changing from 271 to 272 lbs. an increase of only 1 lb. Group A with scab-free barley increased from 380 to 416 lbs. an increase of 36 lbs. These results agree with the reports from several farmers who unsuccessfully tried cooking scabby barley.

To more directly determine the effect of the scab fungus, it was decided to artificially inoculate some of the scab-free 1927 barley. This was done by placing moistened 1927 barley in cotton stoppered quart Mason jars and autoclaving to destroy all saprophytic organisms. A pure culture of *Gibberella saubinetii* which had been isolated from scabbed barley was used to inoculate this material. In order that the material in the jars might be as uniformly penetrated as possible a three-quarter inch glass tube was placed in each jar before filling. The culture of Gibberella had been carried on autoclaved barley in preparation dishes and the glass tube in each Mason jar was filled with the inoculated barley. The tube was then withdrawn leaving a central core of barley with Gibberella from which the fungus spread uniformly through the jar.

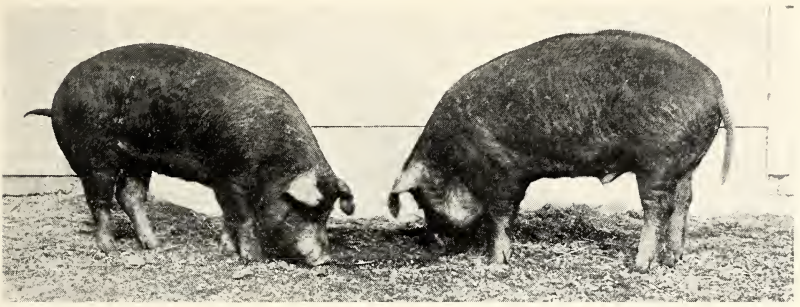

Fig. 3—Two hogs fed scab-free barley. These weighed 275 lbs. at the beginning of the test and at the end, 60 days later, weighed 442 lbs. an increase of 167 lbs.

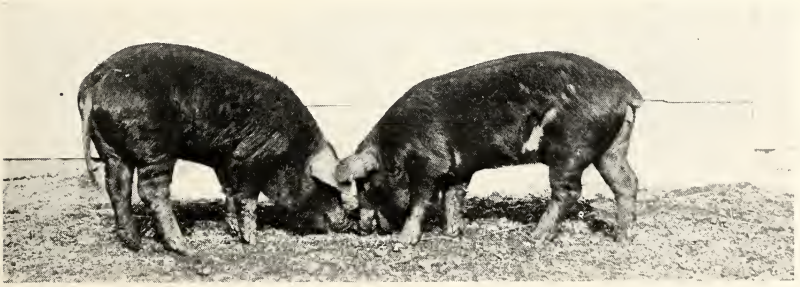

Fig. 4—Two hogs fed scabby barley. These weighed 275 lbs. at the beginning of the test and at the end, 60 days later, weighed 274 lbs. a decrease of 1 lb.

It took the culture about 9 days to thoroughly penetrate the barley. The barley was then removed and rapidly dried at a temperature of about 70° C. Since the development of the fungus in this material was much more extensive than in any of the cases under field conditions, this artifically scabbed material was mixed with the original scab-free barley so that the ration consisted of 1 part artifically scabbed barley, 8 parts scab-free barley and 1 part of tankage.

This ration was then fed for six days to Group A which had been carried for 39 days on scab-free barley with an average gain of 3.6 lbs. per day for the two pigs. These pigs immediately lost appetite and dropped from 416 to 412

lbs., a loss of 4 lbs. Group B on naturally scabbed barley during the same time showed a slight increase from 272 to 273 lbs. Group C on scabby cooked barley dropped from 240 to 235 lbs., a loss of 5 lbs.

Group A was then changed back from the artifically scabbed barley to their original scab-free barley ration and in the next 9 days increased from 412 lbs. to 442 lbs., an increase of 30 lbs. Group B on scabby ground barley increased from 273 to 274 lbs., an increase of only 1 lb. and Group C on scabby whole cooked barley increased from 235 to 244 lbs. or 9 lbs.

During the 60 days of this experiment, group A on scab-free barley (including 6 days on artificially scabbed when weight was lost) increased from 275 to 442 lbs., (fig. 3) an increase of 167 lbs. or an average daily increase per pig of 1.39 lbs. During the same period, the two pigs of group B on ground scabby barley were just about able to maintain their weight (fig. 4) since they weighed 274 lbs. at the end of the experiment. Group C fed on scabby barley with various treatments dropped from 275 to 244 lbs., a reduction which was produced mostly while feeding molasses with the ration.

This experiment shows that pigs are able to make good gains on barley when it is free from scab. However, when such scab-free barley was artificially scabbed and fed, the pigs immediately ceased gaining and finally lost in weight. While the scabby barley did not make the pigs sick, there was a reduced consumption of such barley. These pigs made no gain in weight. Modification of the scabbed barley ration with molasses and cooking did not make such barley more edible.

Experiment 3. Experiments with Rats. On September 9, an experiment was started using 9 young white rats. These were divided into three groups. Group A consisting of three rats weighing 67, 40 and 40 grams totaling 147 grams was fed ground scab-free barley from the 1927 crop. Group B containing three rats weighing 68, 34 and 52 grams totaling 154 grams was fed ground barley (lot A same as used in experiment 1 with pigs) containing 58% of scabby kernels. Group C, containing three rats weighing 70, 36 and 45 grams totaling 151 grams was fed ground scabbed barley of another lot (C) containing 64% of scabby kernels which however were not as thoroughly penetrated by the fungus as in lot A.

A decided difference in the consumption of the feed was immediately noted. During the first seven days the rats of group A on scab-free barley ate 205 grams while rats of group B on scabby barley (A) only ate 83 grams and the rats of group C on scabby barley (C) ate 96 grams. The three rats of group A at the end of the seven days weighed 196 grams, an increase of 49 grams. Group B weighed 120 grams, a decrease of 34 grams, and one rat of this group died on the seventh day. The rats of group C weighed 150 grams, a decrease of 1 gram.

The scabby barley of lot A had much more pronounced results since one rat of group B died on the seventh day, the second on the tenth day, and the third on the twenty-first day. In group C on scabby barley C, one rat died on the eleventh day while the other two lived until feeding was discontinued at the end of the twelfth week. The rats of group A on scab-free barley were fed for 15 weeks and were all alive at the end of the experiment.

The average weekly consumption of food per rat for the rats of group A on scab-free barley was 81 grams, for rats of group B, 30 grams and for group C, 43 grams. The rats of the group on scab-free barley averaged a gain of 11 grams per week per rat for fifteen weeks. The rats of group B lost on the average 8

grams a week per rat during the period they were alive. The rats of group C averaged a gain of 4 grams a week per rat during the period they lived.

The results in this experiment are very similar to those obtained with pigs except that the scabby barley was more toxic and brought about death in several cases. Such rats were examined in the veterinary department and no signs of disease were noted.

Experiment 4. On October 16, another experiment was started using older rats. Two rats weighing 164 and 137 grams averaging 150 grams, constituting group F, were fed scab-free barley. Group G containing three rats weighing 148, 154 and 158 grams, averaging 153 grams, were fed scabby barley of lot B used in feeding pigs. This feeding test ran for three weeks. The rats of group F consumed an average of 126 grams of feed per week per rat while those of Group G consumed 104 grams per week. The rats of group F showed an average gain in weight of 47 grams while those of group G averaged 12 grams.

Experiment 5. On October 25, an experiment was started using barley artificially inoculated with scab as described in experiment 2. This was fed to a group D of three rats weighing 126, 114 and 98 grams, totaling 338 grams. Another group E of three rats weighing 113, 126, 118 grams totaling 357 grams was fed scabby barley of lot B which had been cooked. At the end of the first week group D had consumed 173 grams of feed and group E 155 grams. During the same period group A on scab-free barley had consumed 278 grams. The weight of rats of group D decreased 49 grams. The weight of the rats of group E decreased 37 grams while the weight of rats in group A fed scab-free barley increased 34 grams during the same period. One rat of group D died at the end of the first week. The other two, for another week, gained some in weight but were still 4 grams below their original weight. Artificially scabbed barley therefore produced similar results and cooking did not destroy the objectionable principal.

Experiment 6. Experiment with Guinea Pigs. One experiment with guinea pigs was also tried. One group A, containing two pigs weighing 223 and 232 grams, totaling 455 grams was fed ground scab-free barley. A second group B containing two guinea pigs weighing 262 and 198 grams, totaling 460 grams was fed ground scabby barley B. A third group containing two guinea pigs weighing 206 and 278 grams totaling 484 grams was fed ground scabby barley C. At the end of the first week group A had consumed 275 grams of the scab-free barley, group B only 55 grams of scabby barley A, one dying on the third day and the other on the fourth and group C, 175 grams of scabby barley C. Group A had increased 22 grams in weight. Group B decreased 87 grams and group C decreased 27 grams. After the first week, all of the guinea pigs lost in weight. One guinea pig of group C died at the end of 17 days and the other after 21 days, and in group A after 21 days and 22 days.

Although the guinea pigs in this experiment were not able to develop even on the scab-free barley, the scabby barley was still less favorable.

Experiments with Dairy Cattle. Through the kindness of Prof. H. W. Gregory and Prof. J. H. Hilton of the Dairy Department we are allowed to quote some of the results obtained in feeding experiments with dairy cattle. A ration consisting of 5 lbs. of the scabby barley A used in the previous experiments, 2 lbs. of oats, 1 lb. of bran, 1 lb. linseed oilmeal together with alfalfa hay and silage was fed. This was fed to three cows for 10 days. The cows ate the mixture

readily and no effect was noted on weight, physical condition, milk production or milk quality as compared with the previous ten days. These results agree with reports of farmers who were able to feed cattle scabby barley which they were not able to feed to hogs.

Experiments with Poultry. Through the kindness of Prof. C. W. Carrick and Prof. R. E. Roberts of the Poultry Department we are allowed to summarize the results obtained in feeding experiments with poultry. Scabby barley A made up 20% of a ration with yellow corn, wheat bran, wheat middlings, meat scraps and cod liver oil. This was fed for 5 weeks to 15 eight-week old chicks and to 10 pullets in comparison with a similar ration containing 20% of scab-free barley. There was no reduced palatability due to the scabby barley. The feed consumption of the scabby barley as compared with scabbed-free was slightly greater for the pullets while slightly less for the chicks. There was very little difference in increase in weight between those fed scabby and scab-free barley, the pullets increasing slightly more on the scabby and the chicks slightly more on the scab-free.

SUMMARY. In these studies, hogs found scabby barley distasteful. The consumption was decreased, only enough being eaten to keep from starvation. No cases of vomiting were noted. It seems likely that vomiting probably occurred when hogs ate excessive amounts of the scabby barley with resulting excessive digestive disturbances.

Scabby barley can be fed to hogs as a small part of the ration. The proportion will depend upon the amount of scab in the grain. Since barley containing 35% of moderately scabby kernels had to be reduced to one-third of the ration before the pigs gained in weight, probably it can not successfully be fed when more than 10% of the ration. Since lots of barley differ widely in the amount of scab, the proportion of mixture can best be determined by trial.

Scabby barley can be utilized with cattle. Barley containing up to 58% of scab being successfully fed as 50% of the grain ration. It may also be utilized as 20% of the grain ration for poultry.

While there is no method known by which scab can be completely controlled in Indiana, the disease may be greatly reduced. As already stated the fungus is carried over winter on rubbish, specially corn stalks, straw, etc. It is, therefore, much more severe when wheat is planted in standing corn or where such material is imperfectly plowed under and can be reduced by thoroughly plowing under all crop residues before planting to small grains.

There is considerable evidence accumulating that a choice of varieties may greatly reduce losses from this disease. The varietal susceptibility of winter wheats have not been studied long enough under Indiana conditions to justify recommendation.[18] Among spring wheats, Illinois No. 1, Norka and Progress [19] [20] have shown outstanding resistance[21] (1. c. 2). Among the barleys several strains of Manchuria and Oderbrucker have been very promising. Hooded varieties should be avoided since they are very susceptible.

[18]The relative susceptibility of winter wheat varieties in Missouri has been reported by I. T. Scott. Varietal Resistance and Susceptibility to Wheat Scab. Mo. Agr. Exp. Sta. Res. Bul. 111. 1927.

[19]E. B. Mains. Observations Concerning the Disease Susceptibility of Cereals and Wild Grasses. Proc. Ind. Acad. Sci. **34**:289-295. 1925.

[20]J. G. Dickson, E. B. Mains, and Helen Johann. Progress Report on Cereal Scab Development During the Season of 1928. Phytopath. **19**:108. 1929.

[21]The relative susceptibility of spring wheat varieties in Minnesota has been reported by J. J. Christensen and E. C. Stakman. Susceptibility of Wheat Varieties and Hybrids to Fusarial Blight in Minnesota. Univ. Minn. Agr. Exp. Sta. Tech. Bul. 59, 24 p. 1929.

HYDROGEN-ION REACTION OF NATIVE INDIANA FERN SOILS

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This paper is only the minor beginnings of what is intended in this research. One could collect and test for years and still be undecided about the exact acid and alkaline tolerance span of each of our Indiana ferns.

Three samples of ferns and of root soils of each species are collected from three different places in the same locality. Each frond is pressed and labeled as to county in which it was collected, date, type of association and soil. Each soil sample is placed in a sack and labeled as above also. The fronds are collected for herbarium sheets while the soils are obtained for tests which are made in the laboratory.

The Youden Hydrogen-ion Consentration apparatus is used in determining the acidity of these soil samples. The e.m.f. in volts are then converted into pH results. These results from the three separate samples of each species from each locality are tabulted and averaged on a card. Of course the more collecting done the more cards one will have for each species and the more accurate the tolerance range can be determined.

So far in this research definite conclusions are hard to draw. No species have been found in superacid soils. Certain species though, like *Aspidium cristatum* (Crested wood fern) and *Osmunda cinnamomea* (Cinnamon fern) are found to grow in highly mediacid soils. With more collecting they may be found in low superacid soils. *Dicksonia punctilobula,* (Hay scented) *Pteris aquilina* (Common Brake) *Polypodium vulgare,* (Polypody) and *Osmunda regalis* (Royal) are found limited to mediacid region but it is felt that there is a much broader variation here than what is shown. Other species such as *Ophiglossum vulgatum* (Adder's tongue) *Aspidium spinulosum, Woodsia obtusa* (Rusty) *Aspidium marginale,* (Marginal shield) and *Osmunda Claytoniana* (Interrupted) are found in subacid soils—the two later are low in subacid or nearly high minimacid. Aspidia as a rule show a broad range. There is no one species found limited to a highly alkaline soil but there are various species as *Aspidium Thelypteris* (Swamp) and *Polystichium acrostiochoides,* var. *Schweinitzii* which have a very broad tolerance from minimalkaline up to mediacid in the former and subacid in the latter. The wide variation of the swamp fern is not to be considered surprising since it is often found in a rather high acid soil with peaty substrata or growing more often in a foot or so of water. *Polystichium acrostiochoides* var. *Schweinitzii* shows a broad circumneutral range, yet *Aspidium Goldianum* (Goldie's Wood fern) grows in a low minimalkaline soil and has a narrow range in so far as the reactions to date denote.

Two species of the same genus, *Cystopteris fragiles* (Fragile) and *Cystopteris bulbifera* (Bladder), plus *Asplemium platyneuron* (Ebony spleenwort) and possibly *Polystichium acrostiochoides* all show a range of weak alkaline to a weak acid soil reaction. The latter found in various localities of Indiana indicates that it is on the average a subacid plant but which also has a low alkaline limit. *Onoclea sensibilis* (Sensitive) and *Botrychium virginianum* (Rattlesnake fern) reveal a

broad soil tolerance from subacid to a strong alkaline strata. In between the extremes there are a few ferns that show a broad range but on the average they are minimacid soil plants. These include *Asplenium filix-femina* (Lady fern), *Camptosorus rhizophyllus* (Walking fern), *Asplenium acrostichoides* (Silver spleenwort), *Phegopteris hexagonoptera* (Beech), *Adantum pedatum* (Maiden-hair), and *Asplenium angustifolium* (the Narrow-leaved spleenwort).

From localities found it seems that the walking fern and the narrow-leaved spleenwort should be more nearly alkaline but so far results do not show it.

It will be interesting to note how the next collection of ferns will change or verify the present results.

The following is a table showing present results.

SPECIES (Nomenclature after Gray's Manual, 7th Ed.)	Number of Samples	pH Range	Characteristic Reaction	Natural Type of Association and Soil of the species
1. Adiantum pedatum (Maiden-hair fern)	9	5.8-7.3	High minimacid	Various mesophytic woodlands drained soils.
2. Aspidium cristatum (Crested wood fern)	3	4.3-4.5	High mediacid	Interior of bog thicket with Rhus vernix, Populus tremuloides. Peat substratum.
3. Aspidium Goldianum (Goldie's Wood fern)	3	7.0-7.3	Low minimalkaline	Rocky and wooded river valley. Damp shaded; alkaline drained soil.
4. Aspidium marginale (Marginal shield-fern)	6	5.4-6.5	Low subacid	Low mesophtic woodland and cliffs. Washed, drained, clay loam soils.
5. Aspidium noveboracense (New York fern)	6	4.9-6.6	Subacid	Various beech and maple woodlands. Well drained silt.
6. Aspidium spinulosum	6	4.3-6.2	High subacid	Interior of bog thicket and sandy cliff base. Damp or peaty substrata.
7. Aspidium Thelypteris (Swamp fern)	9	4.4-7.2	Low subacid	In wet meadows around bog margins and in boggy spring area. Peat and muck soils.
8. Asplenium acrostichoides (Silver Spleenwort)	7	4.5-7.6	High minimacid	Dense growth of beech, maple, poplar, etc. Well drained, rich clay loam.
9. Asplenium angustifolium (Narrow-leaved spleenwort)	6	6.6-6.8	Minimacid	Low wooded creek bottoms or slopes. Soil damp, sandy loam.
10. Asplenium Filix-femina (Lady fern)	9	5.4-6.7	Minimacid	Wooded upland and hillsides with Beech fern, etc. Sandy clay loam.
11. Asplenium platyneuron (Ebony Spleenwort)	9	6.0-7.6	Low minimacid	Wooded underbrush of hillsides and cliff base. Sandy shale, dry.
12. Botrychium virginianum (Rattlesnake fern)	10	5.4-7.1	High minimacid	Woodland. Shale and clay loam.
13. Camptosorus rhizophyllus (Walking Leaf fern)	3	6.4-6.6	Minimacid	On rocks or cliffs in damp and shady gorge. Leafmold and sandy loam.
14. Cystopteris bulbifera (Bladder fern)	4	6.7-7.6	Low minimalkaline	Deep and damp wooded gorge. Leafmold and sandy shaled cliffs.

SPECIES (Nomenclature after Gray's Manual, 7th Ed.)	Number of Samples	pH Range	Characteristic Reaction	Natural Type of Association and Soil of the species
15. Cystopteris fragilis (Fragile fern)	13	6.1-7.7	Low minimacid	Scattered from wooded upland to lowland weedy patches. From damp to well drained clay loam.
16. Dicksonia punctilobula (Hay scented fern)	3	4.9-5.0	Low mediacid	Growing rank on wooded well-drained hillsides in sun or shade. Red sandy soils.
17. Onoclea sensibilis (Sensitive fern)	16	5.4-7.8	Minimacid	Open, high and sloping hillsides and at marsh edge with Salix nigra. Rich loam or peat substrata.
18. Ophiglossum vulgatum (Adder's Tongue fern)	3	5.2-6.0	Subacid	Sassafras-aspen thicket on hillside. Poor clay loam not well drained.
19. Osmunda cinnamomea (Cinnamon fern)	3	4.3-4.5	Mediacid	Interior of bog thicket. Sandy clay and peat substrata.
20. Osmunda Claytoniana (Interrupted fern)	6	5.5-6.1	Low subacid	Shaded wooded hillsides. Damp shale and sandy clay.
21. Osmunda regalis (Royal fern)	3	4.5-4.7	Mediacid	In wet meadows and interior of bog thicket. Muck and peat substrata.
22. Phegopteris hexagonoptera (Beech fern)	12	4.8-7.9	High minimacid	Open or dense sloping woodland. Maple, beech and oak. Drained silt and clay loam.
23. Polypodium vulgare (Polypody or Hardy Cliff fern)	4	4.4-4.9	Mediacid	Overhanging rocky cliff. Sandy loam soil.
24. Polystichium acrostichoides (Christmas fern)	12	5.3-7.4	Minimacid	Everywhere on hillsides and wooded glens. Clay or silt well drained.
25. Polystichium acrostichoides var Schweinitzii	8	6.0-8.0	Circumneutual	Low floodplain or shaded hillside. Silt or clay well drained.
26. Pteris aquilina (Common Brake fern)	3	4.4-4.6	Mediacid	Wooded rock cliff. Damp shale.
27. Woodsia obtusa (Rusty fern)	3	6.3-6.9	Minimacid	Beech, maple woods. Well drained silt.

In conclusion it can be said that the type of ecological investigation here undertaken finds immediate practical application in fern culture. With knowledge of the native soil types, with special reference to acidity, and of the vegetation types with which the various species are most frequently associated, greater assurance of success can be had in the cultivation of many highly desirable native species of ferns.

I wish to recognize Prof. Ray C. Friesner of Butler University for helpful interest and the use of laboratory apparatus, and Assoc. Prof. Stanley A. Cain, who suggested this problem for investigation.

PTERIDOPHYTES OF TURKEY RUN STATE PARK

FREDERICK H. TEST, West Lafayette

Since an annotated list of the ferns of Turkey Run was published by Otto Behrens, Jr., in the proceedings of this Academy for 1927, there have been numbers of inquiries made of the guides at the Park, both by individuals and botany classes, about the ferns to be found there. Therefore, as several more species and varieties have been added to the 1927 list, a few identifications in that list have been found to be incorrect, and distributions in the Park have been further determined, this paper is published as a revision of the one of 1927.

There are few counties in Indiana which can boast such an abundance of ferns, both as to species and to individuals, as Parke County; and Turkey Run offers a wonderful cross-section of the county's fern flora. Gypsy Gulch just back from the south side of Sugar Creek and about three-eighths of a mile above the suspension bridge has a greater abundance of individuals, representing about 12 species and varieties, than any other area of the same size in the Park. The section of the Park lying east of Newby Gulch and south of Sugar Creek is probably the best for study by visiting classes with only a few hours at their disposal, as it contains a comparatively large number of species, most of which are common there.

In the last two years more land has been added to the Park, which now comprises over 1,100 acres. However, only two of the areas have much fern life; the tract taking in the head of Turkey Run Hollow and some land along the south side of Sugar Creek at the west end of the Park.

The observations recorded here were made during the summers of 1927, 1928 and 1929 by Sidney R. Esten, Otto Behrens, Jr., Rexford F. Daubenmire and the writer, while stationed as nature guides in the Park for the Indiana Department of Conservation. The doubtful specimens have been identified by Ray C. Friesner of Butler University and Mr. Charles C. Deam, and we hope that no corrections to this list will be necessary. As more work is done, however, a few species may be added and some found to be more or less abundant. The writer wishes to thank Prof. Ray C. Friesner of Butler University, Mr. Charles C. Deam of Bluffton, Prof. Albert R. Bechtel of Wabash College, Prof. Truman C. Yuncker of DePauw University, Prof. Paul Weatherwax of Indiana University, and Mr. A. T. Guard and Prof. Louis A. Test of Purdue University for help and suggestions. Unless otherwise stated all records are backed up by specimens in the Turkey Run Nature Guide Service Herbarium at 4112 Graceland Avenue, Indianapolis, in care of Sidney R. Esten. The nomenclature adopted here is the one now in use at the Gray Herbarium. Following is the list of species.

1. *Polypodium virginianum* L., Common Polypody is one of the characteristic ferns of the Park. While not as common as some, it is found fairly well distributed on practically all the cliffs. Its preference seems to be for narrow ledges and edges of cliffs, where the roots hold the soil together in a mat.

2. *Adiantum pedatum* L. American Maidenhair is a common and typical fern throughout the area, preferring the rich moist soil along streams in fairly open woods, where it attains a large size. On almost any hillside covered with humus, however, it can be found.

3. *Pteridium latiusculum* (Desv.) Hieron. Bracken. This summer was the first time we found this fern in the vicinity of Turkey Run. As far as we know, it is very rare. The only specimens found were outside the Park in the open at the edge of a sandy field bordered by second growth timber, uncultivated that year. Only ten fronds were found ranging in height from about one to two feet. It was not determined whether all were from the same plant, but the arrangement and nearness of the fronds would seem to indicate that perhaps there was only one plant. Rather careful search was made in the vicinity but no others were found. This spot and the surrounding land will be watched carefully in the future.

4. *Pellaea atropurpurea* (L.) Link., Purple Cliffbrake. Although reported a few years ago by several persons, this species evidently died out in those spots and was not found by us until this summer. The only specimens discovered were in crevices just below the top of a thirty-foot sandstone cliff along Sugar Creek. The situation was rather dry, exposed and faced south. Due to their position a strictly accurate count could not be made but it was estimated that there were about 75 plants in the colony. None were of very large size.

5. *Asplenium Trichomanes* L., Maidenhair Spleenwort is local and rather rare. It is found on sandstone cliffs mostly in damp situations among mosses, although the largest specimens are in niches of the sandstone where there seems to be comparatively little moisture and no other plants. This colony contains 16 plants, and the others, respectively, eight or ten, and six. These three colonies are, so far, the only ones found in the Park.

6. *Asplenium platyneuron* (L.) Oakes., Ebony Spleenwort is local but fairly common. It is found growing in colonies. All five of the colonies we discovered were in rather open situations and all but one in rocky soil. The smallest contained about 25 plants and the largest perhaps 300 plants.

7. *Athyrium angustifolium* (Michx.) Milde. Narrow-leaved Spleenwort is common throughout the Park in rich soil, especially in fairly open situations along streams, where a height of three feet was sometimes attained. In 1929 the first fertile fronds were found uncoiled on August 4. A fertile frond was found with one of the pinnae bifid at the tip. Another interesting "sport" is a frond which had both fertile and sterile characteristics. The upper pinnae seem to be nearly typical fertile ones except that they are more sparingly fruited. Progressing down the stipe the pinnae become gradually wider and bear less and less sori. The lower three-fourths are of the length and width of normal sterile pinnae. Those bearing sori extend nearly two-thirds of the way down the frond. The ones below are normal sterile ones. Of the last two which bear sori, one has four and the other twelve.

8. *Athyrium acrostichoides* (Sw.) Diels., Silvery Spleenwort was found associated with the preceding species throughout the Park, although not so common.

9. *Athyrium angustum* (Willd.) Presl., Lady Fern is infrequent, scattered in the deeper upland woods where there is plenty of rich humus.

10. *Camptosorus rhizophyllus* (L.) Link., Walking Fern is another characteristic fern of the Park, common throughout in colonies on the sandstone cliffs and on fallen pieces of rock. Some interesting plants were found in fruit, growing in moss on the base of a large sycamore. Several were queerly auricled at the base and others were once, twice, and three times bifid.

11. *Polystichum acrostichoides* (Michx.) Schott., Christmas Fern is common in practically all parts and abundant on the humus-covered hillsides. A few

plants were found which had fronds with the lowest two or three pairs of pinnae somewhat abortive. Instead of their bases being halberd-shaped, each one had an ear-like appendage which was free from the rest of the pinna except for one point of attachment.

12. *Polystichum acrostichoides* forma *incisum* (Gray) Gilbert. Scattered over the Park were a few specimens of this variety. They were rather rare and in the same situations as the species.

13. *Thelypteris palustris* Schott., Marsh fern, was found growing in only one place in Turkey Run—along an old fill near the covered bridge. There is quite a colony among the tall grass in a small, swampy area.

14. *Thelypteris noveboracensis* (L.) Nieuwl., New York Fern. Although not as common as some, there are several colonies of this fern. Open sunny spots on the uplands in rather dry gravelly soil seemed to be preferred. However, in the silt of the bottoms along Sugar Creek a colony was found growing in quite dense shade. No fertile fronds were found during a fairly thorough examination of the colony.

15. *Thelypteris hexagonoptera* (Michx.) Weatherby., Winged Beechfern is common in the rich humus of all the upland woods areas in the Park.

16. *Thelypteris marginalis* (L.) Nieuwl., Leather Woodfern is abundant throughout the Park especially in the rich loam of rocky hillsides. With *Thelypteris spinulosa* and its variety it is probably the most common species in the Park.

17. *Thelypteris marginalis* forma *elegans*. (J. Robinson) Weatherby. A few specimens of this variety were found among an abundance of the species in the humus on a rocky hillside back from Sugar Creek.

18. *Thelypteris Goldiana* (Hook.) Nieuwl., Goldie's Fern is rather infrequent. It is found in several ravines, principally on the north side of the river. Prefers the same type of soil as *Thelypteris marginalis* but in the ravine bottoms instead of on the hillsides.

19. *Thelypteris spinulosa* (O. F. Muell.) Nieuwl., Toothed Woodfern is very common and growing in nearly all situations. Among the rotting dead leaves on broad ledges and at the bases of cliffs it forms beautiful luxuriant growths. The distribution and abundance of this and the following variety have not yet been worked out to any extent.

20. *Thelypteris spinulosa* forma *intermedia* (Muhl.) Nieuwl., is found in the same situation as the species but probably somewhat less common.

21. *Cystopteris bulbifera* (L.) Bernh., Berry Bladderfern is common in wet situations at bases of cliffs and along streams throughout the region.

22. *Cystopteris fragilis* (L.) Bernh., Brittle Fern is common in all upland woods. The first of the mid-summer new fronds were noted July 2 in 1929.

23. *Woodsia obtusa* (Spreng.) Torr., Common Woodsia is found sparingly on most of the dryer cliffs in Turkey Run and also on some fallen pieces of sandstone on the north side of Sugar Creek.

24. *Dennstaedtia punctilobula* (Michx.) Moore., Hayscented Fern is rare. It grows in only three places in the Park—on a broad ledge in Rocky Hollow on the north side and on two hillsides, one rough and the other smooth, within a few hundred yards of each other on the south side. All are open situations.

25. *Onoclea sensibilis* L., Sensitive Fern is frequent but restricted to the swampy regions, which are rather few in Turkey Run.

26. *Osmunda Claytoniana* L., Interrupted Fern is infrequent. Only a few plants are found scattered in groups of two to six in moist spots throughout the Park.

27. *Botrychium virginianum* (L.) Sw., Rattlesnake Fern is frequent in moist, rich woods in the region.

It is quite probable that *B. obliquum* and *B. dissectum* will also be found in Turkey Run but we have had no opportunity to find them, due to their time of appearance and no authentic records of their discovery by others have been noted.

28. *Equisetum arvense* L., Common Horsetail is frequent in several open swampy places in the Park, especially near the colony of *Thelypteris palustris* and up Turkey Run Hollow.

29. *Equisetum hyemate* L., Scouring Rush is more common than the preceding. There are several dense stands on the banks of Sugar Creek

30. *Lycopodium lucidulum* Michx., Shining Club Moss is scattered sparingly in most of the canyons on the humus-covered sandstone ledges.

31. *Selaginella rupestris* (L.) Spring., Rock Selaginella. This species was overlooked by us and the only record known has been kindly furnished by Charles C. Deam. In his herbarium is a specimen (No. 34,999) of this plant with the following notes: "On sandstone rock in Sugar Creek at the "Narrows" in Turkey Run State Park; Sept. 21, 1921." Whether it is still there is not known.

32. *Selaginella apus* (L.) Spring., Creeping Selaginella. So far as we know the only place in the Park where it grows is in the open among the grass on the same piece of marshy ground as *Thelypteris palustris* where it is fairly common.

A SIMPLE RESPIROMETER FOR QUANTITATIVE CLASS EXPERIMENTS

Raymond E. Girton, Purdue University

It is desirable that students in plant physiology be able to verify experimentally some of the known facts concerning respiration. In order to meet this need, a simple and inexpensive respirometer was devised for following the respiration of germinating seeds over rather short periods of time. This device is based upon the well known principle of determining the oxygen absorbed in respiration by manometric measurements of the resulting reduced air pressures. The carbon dioxide evolved is immediately absorbed by a sodium hydroxide solution so that the production of this gas has no effect upon the pressure of the atmosphere within the apparatus.

The respirometer consists of a large test tube (2.5 x 20. cm.) fitted with a two-holed rubber stopper, a U-shaped capillary-tube mercury manometer, a short glass rod about 3 cm. long and a small perforated cardboard disk. The arrangement of the apparatus may be seen in the accompanying diagram (Fig. 1).

In setting up an experiment, 5 c.c. of a strong solution of sodium hydroxide is first run into the bottom of the test tube from a pipette. Following this the

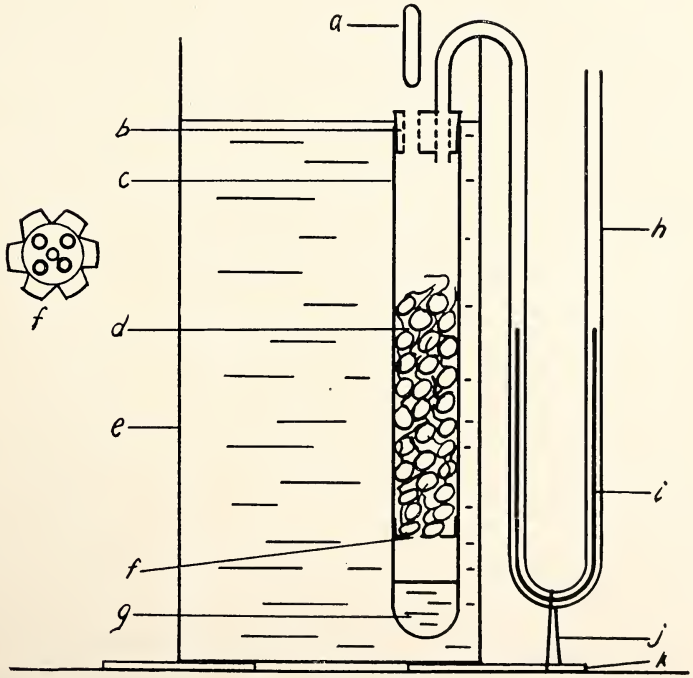

Fig. 1—Test-tube Respirometer. (a) glass plug, (b) rubber stopper, (c) test tube, (d) germinated peas, (e) water bath, (f) cardboard disk, (g) NaOH solution, (h) manometer, (i) mercury (j) rubber band, and (k) wooden strip.

cardboard disk, which should be coated with paraffin, is pushed down the test tube to a point about 2 cm. above the surface of the sodium hydroxide solution. At this time the apparatus is ready for the plant material. Garden peas sterilized with 0.4% Uspulun and germinated between moist blotting papers for 3 or 4 days have proved highly satisfactory for this work. Fifteen grams of this material is placed in the tube and the rubber stopper containing the manometer inserted in the mouth of the test tube. The respirometer *with the glass plug removed* may then be placed in the water bath maintained at the desired temperature. The respirometer is held in place by means of a rubber band stretched tightly between the manometer tube and one of several small wooden strips upon which the water bath rests. (Fig. 1). About 15 minutes with frequent stirrings of the water bath should be allowed for the temperature adjustment to take place.

After sufficient time has elapsed for the temperature adjustment, the glass plug should be inserted in the rubber stopper, the manometer tube tapped vigorously and the mercury levels in the manometer marked. This may be done by sticking a narrow strip of gummed paper on the back of the manometer tube, level with the meniscus of each of the two mercury columns. The time at which the manometer tube is tapped should be taken as zero time. Manometric readings may then be taken at stated intervals of time (5, 10 or 15 minutes) with the aid of a small millimeter scale. They must be preceded by a vigorous tapping of the manometer tube to facilitate the adjustment of the mercury columns.

When sufficient readings have been taken to satisfy the purpose of the experiment, the respirometer is removed from the water bath and the volume of the air space within the test tube determined. This is done by removing the glass plug and inserting the narrow outlet tube of a burette loosely through the hole in the rubber stopper. The volume of water required to fill the respirometer gives the volume of the internal atmosphere. The small gas volume in the capillary manometer tube may be neglected without involving serious error.

Data collected should include the manometric readings at known times, the volume of the air space within the loaded respirometer, the temperature of the water bath and the barometric pressure. In the absence of a barometer, an atmospheric pressure of 760 mm. may be assumed without seriously impairing the usefulness of the method.

Calculations of the amounts of oxygen absorbed are based upon the data just indicated and the gas laws respecting changes in volume with regard to pressure and temperature. Changes in the mass of the gas, due to the absorption of oxygen, are neglected for the sake of simplicity. While this factor should be considered for the higher accuracy required in research, it is believed that their inclusion here would only complicate matters for the student. The method of calculation may be seen from a study of the following table.

Respiration data for 15 gms. of germinated peas at 25°C.

TIME	Manometer Reading			Internal* Pressure	Internal Volume†		Oxygen‡ Absorbed
	Left Arm	Right Arm	Total		at 25°C.	at 0°C.	
0 hrs.	0.0 mm.	0.0 mm.	0.0 mm.	760. mm.	56.5 cc.	51.8 cc.	0.0 cc.
0.25 hrs.	4.5 mm.	4.5 mm.	9.0 mm.	751. mm.	55.8 cc.	51.1 cc.	0.7 cc.
0.50 hrs.	10.5 mm.	10.5 mm.	21.0 mm.	739. mm.	54.9 cc.	50.3 cc.	1.5 cc.
0.75 hrs.	15.5 mm.	15.5 mm.	31.0 mm.	729. mm.	54.2 cc.	49.6 cc.	2.2 cc.
1.00 hrs.	21.5 mm.	21.5 mm.	43.0 mm.	717. mm.	53.3 cc.	48.8 cc.	3.0 cc.
1.25 hrs.	28.0 mm.	28.5 mm.	56.0 mm.	704. mm.	52.3 cc.	47.9 cc.	3.9 cc.
1.50 hrs.	34.5 mm.	34.5 mm.	69.0 mm.	691. mm.	51.3 cc.	47.0 cc.	4.8 cc.

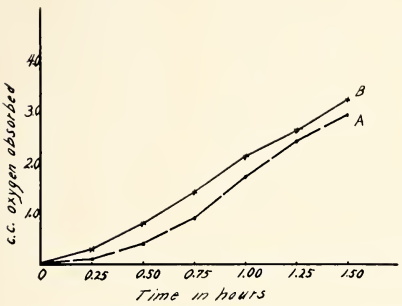

Fig. 2—Respiration of germinating peas at 25°C. Duplicate determinations for two 15 gm. (fresh weight) samples.

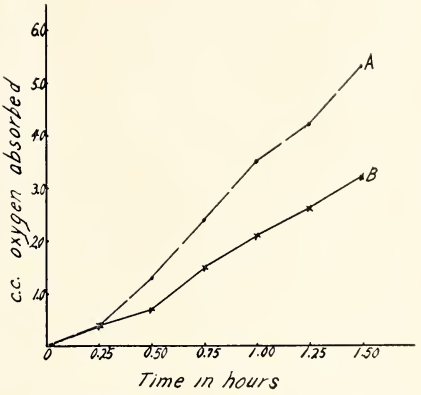

Fig. 3.—Effect of temperature on the respiration of germinating peas. A = oxygen absorption of 15 gms. of peas at 30°C. B = same at 20°C.

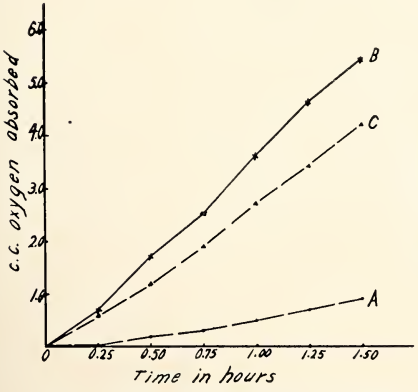

Fig. 4—Respiration of germinating peas at different stages of germination. A = 1 day from sterilization, B = 3 days and C = 5 days from sterilization. Temperature 25°C. Data taken on 15 gm. samples.

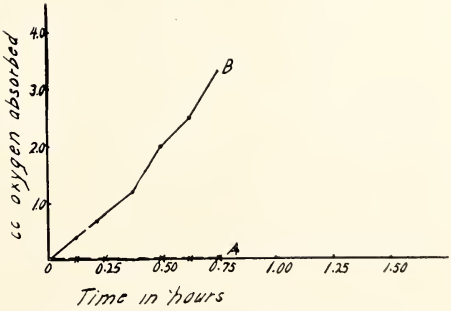

Fig. 5—Effect of steam treatment on respiration of germinating peas at 25°C. A = oxygen absorption of 15 gms. peas autoclaved for 10 minutes. B = same for untreated peas.

*Internal atmospheric pressure = barometric pressure − manometer reading.

†Internal volume = measured air space volume $\times \frac{\text{Internal pressure}}{\text{Barometric pressure}}$

This value for the internal volume at 25°C. is then reduced to standard temperature by multiplying by the factor $\frac{273}{273 \text{ plus } 25}$ or 0.916.

‡Oxygen absorbed at N. T. P. = Initial internal volume − internal volume at any given time.

The course of aerobic respiration as determined by the absorption of oxygen may be shown graphically by plotting oxygen consumption against time. This has been done for duplicate determinations as shown in figure 2. Curve A is plotted from the data given in the preceding table. A second experiment performed in duplicate gave a very similar set of parallel curves.

In addition to demonstrating the normal course of respiration, experiments may also be performed by the student to demonstrate the relation of temperature to respiration. Figure 3 represents a typical set of duplicate experiments in which the respiration of two similar samples of germinated peas was determined. The temperatures studied were 20 and 30° C. In the graph the volumes of oxygen absorbed in each case are again reduced to normal temperature and pressure conditions. This makes the results entirely comparable.

That the respiration of germinating seeds changes with time may be demonstrated experimentally as is shown in figure 4. These results, based upon equal fresh weights of material, indicate that the magnitude of respiration increases with time from sterilization for a period of several days and then decreases markedly.

Figure 5 shows the result of killing the fresh material with steam. The peas autoclaved for 5 minutes showed practically no oxygen absorption while the control experiment exhibited the usual rate of respiration.

Other factors influencing respiratory activity, such as the action of certain cell toxins, may occur to the student and be tested quantitatively with this apparatus. Once the student's interest is aroused, he will probably wish to try various experiments for himself.

PLANTS NEW OR RARE IN INDIANA. XV

Chas. C. Deam, Bluffton

Specimens of the plants reported in this paper are in the Deam Herbarium and the determinations have been checked by specialists.

Thelypteris Filix-mas (L.) Nieuwland, (*Aspidium Filix-mas* (L.) Sw. of Gray's Man. ed. 7 and *Dryopteris Filix-mas* (L.) Schott of Britton and Brown's Ill. Flora, ed. 2.) This species was reported for Indiana in 1881 by the Editors of the Botanical Gazette without locality in a catalogue of the plants of Indiana. It was next reported for Jefferson County successively by J. M. Coulter, A. H. Young, and C. R. Barnes. Stanley Coulter, in his catalogue of the plants of Indiana published in 1900, repudiated all records without comment and placed the species in a doubtful list. I have a specimen from Wells County which was named for me by a specialist as belonging to this species and I reported it as new to the state in the Proc. Ind. Acad. Science for 1905. I have re-examined this specimen and I now refer it to *Thelypteris Goldiana* (Hook.) Nieuwl. Since the species is not listed in Schaffner's flora of Ohio or in Beal's flora of Michigan and its general range is far north of Indiana, I believe the species should be dropped from our flora.

Pteretis nodulosa (L.) Raf., (*Onoclea Struthiopteris* (L.) Hoffm. of Gray's Man. ed. 7 and *Matteuccia Struthiopteris* (L.) Todaro of Britton and Brown's Ill. Flora, ed. 2.) This species was first reported for Indiana in 1881 in a catalogue of the plants of Indiana published by the Editors of the Botanical Gazette. The only data given is that the specimen was from Montgomery County. The same data appeared in Coulter's catalogue of the plants of Indiana and also in Greene's fern flora of Indiana. Pepoon in his flora of the Chicago region mentions this species on page 127 in a general write up of the species of the region but does not specifically say it occurs in Indiana in his flora. This year I was guided by Mr. and Mrs. Walter Neff of Delphi to a large colony of it on an alluvial wooded flat in a woods about two and a half miles southeast of Lake Cicott in Cass County. The collection is my 47,140 and a duplicate is deposited in the Gray Herbarium.

Eleocharis calva Torrey. (*Eleocharis palustris* var. *calva* (Torr.) Gray of Gray's Manual.) I have it from Allen, Boone, Fountain, Fulton, Jennings, Lagrange, Marshall, Noble, Steuben, and Tipton counties. This species was first reported for the state by Hill in the Botanical Gazette 8:187. 1883, for the shore of Cedar Lake, Lake County.

Eleocharis ovata (Roth) R. & S. (See Rhodora 31:211-214. 1929.) The general range of this species is to the north of Indiana. Newton County, Sept. 17, 1929, No. 47,825. In a dredged ditch about four miles southeast of Conrad. Rare here.

Eleocharis Smallii Britton. I have this species from Cass, Elkhart, Fulton, Jasper, Lagrange, Lake, Laporte, Newton, Noble, Owen, Steuben, Sullivan, Vigo, Warrick, and Wells counties.

Eleocharis Torreyana Boeckl. Jasper County, Sept. 21, 1928, No. 46,420. In the bottom of a dry sandy roadside ditch about two miles southeast of Tefft.

Also nearby in a bare place in a dried up marsh where it was associated with *Fimbristylis puberula*, *Hypericum adpressum*, and *Lycopus sessilifolius*.

Scirpus cyperinus var. *Andrewsii* Fernald. Allen County, Aug. 22, 1929, No. 47,635. In a small pond just west of an old school house in the Eli Schlatter woods about three miles northwest of Cedarville. The typical form grew here also but was not quite so mature.

Ranunculus oblongifolius Ell. Dubois County, May 29, 1926, No. 43,073. Frequent in bare open places in the Hunley bottoms about one mile northeast of Huntingburg. Posey County, May 23, 1911, No. 8,311. Frequent in a wet stubble field about four miles southwest of Mt. Vernon. In 1926 and 1929 I found it to be a common plant in a hard white clay soil in a flat undrained fallow field on the Dan Schreber farm about five miles south of Caborn. I found it also along Big Creek about one mile southeast of Wadesville.

Ranunculus pusillus Poiret. This species is closely allied to the preceding with which it might be confused. Our only report of it for the state is that given in Coulter's catalogue of the plants of Indiana. He reports it for Spillman from Knox County. I am referring my specimens 20,372 and 40,184 to this species. They were collected about the middle of May on the border of a pond in a low flat woods about one mile southeast of Palmyra. When collected the plants were in water about six inches deep. In September the area was again visited and at that time it was dry and grown up with sedges and other plants. I also noted it as common around a pond of about two acres about two miles southeast of Palmyra.

Duchesne indica (Andr.) Focke. Spencer County, June 9, 1929, No. 46,756. Common in the talus of a sandstone bluff along the Ohio River in Rockport. I reported this species for Porter County in Proc. Ind. Acad. Science 35:1918. 1926. I am now referring this specimen to *Rubus pubescens* Raf.

Trifolium reflexum var. *glabrum* Lojacono. I reported this variety for Posey County in Proc. Ind. Acad. Sci. 1920:227. 1921. I now have the variety from Clark, Martin, Posey, Spencer, and Vigo counties. It is distinguished from the species by its glabrous calyx lobes. The variety was described in 1883 in an Italian publication and the authors of our manuals overlooked it. The species has been reported for Franklin, Marion, and Vigo counties. I have the Vigo County specimen and it belongs to the variety. No doubt all records for the species should be referred to the variety.

Lathyrus venosus var. *intonsus* Butters and St. John. (Rhodora 19:158-159. 1917.) I have this variety from Fulton, Kosciusko, Lagrange, Lake, Miami, Porter, and Steuben counties. Dr. Lyon also has it from Laporte County. I have the typical species from Harrison County where it is abundant in the talus of a bluff along Blue River about a half mile north of White Cloud. I also have a specimen from Clark County with longer and narrower leaflets than either the typical or varietal forms which I am not able to place.

Crotonopsis elliptica Willd. (Pennell, F. W.: The genus Crotonopsis. Bull. Torrey Bot. Club 45:477-480. 1918.) Spencer County, Sept. 28, 1929, No. 47,973. In a hard white clay soil in a flat undrained open woods and in an adjacent forty acre fallow field about four miles northwest of Chrisney. This area is almost level and wooded with post and pin oaks. It is so poor that the cleared land has been abandoned. In the fallow field the species was very abundant and rare to infrequent in the open woods and absent in the thicker parts of the woods. This species has a range from Connecticut to northern Florida, west to eastern Kansas and central Texas.

Gaura Michauxii Spach. Daviess County, Sept. 21, 1929, No. 47,902. On a sand hill in an open spot on the south side of a black oak woods, owned by Mr. Yates, about one mile southwest of Plainville. It was associated with *Sporobolus canovirens, Bouteloua curtipendula, Andropogon scoparius, Stylosanthes biflora, Liatris squarrosa, Kuhnia eupatorioides, Aster patens,* and other plants that usually have a distinct habitat. The range of this species is Virginia to Kansas, south to Florida and Texas.

Chaerophyllum Tainturieri Hooker. Posey County, June 9, 1929, No. 46,769. Common in alluvial soil along the Louisville and Nashville Railroad about six miles west of Solitude.

Penstemon tubaeflorus Nuttall. Daviess County, June 12, 1929, No. 46,852. On a sand hill about one mile south of Hyatt, associated with black, white, and post oaks. The range of this species is Missouri, Kansas, and Arkansas.

Madia capitata Nuttall. Porter County, July 21, 1929, No. 57,308 of the Field Museum. About a dozen plants on an open bank, Dune Forest near Tremont. Collected by Paul C. Standley of the Field Museum who has permitted me to report this species for him.

Helianthus altissimus L. Lagrange County, Aug. 26, 1924, No. 14,773. At the base of a wooded slope about two and a half miles east of Howe. Also No. 14,992 collected on the low border of the south side of Long Lake northwest of Wolcottville.

Helianthus borealis E. E. Watson. Lagrange County, Aug. 30, 1916, No. 20,963A. Moist sandy roadside one and a half miles east and a half mile south of Mongo. Steuben County, Sept. 20, 1914, No. 15,493. In a dry woods on the east side of Lake James. Collected also in 1904 in low ground in a thick woods on the east side of Clear Lake.

Helianthus exasperatus E. E. Watson. Laporte County, Sept. 15, 1921, No. 34,849. In a prairie habitat five miles northeast of Laporte. Warren County, Aug. 31, 1916, No. 21,603. Dry roadside two miles northwest of Rainsville.

Helianthus teptocaulis (S. Wats.) Blake. Posey County, Aug. 15, 1919, No. 29,081. In a hard clay soil in a flat undrained post oak woods on the south side of Half Moon Pond about ten miles southwest of Mt. Vernon. Tipton County, Sept. 3, 1914, No. 15,355. In a prairie habitat along the right of way of the Lake Erie Railroad about a half mile west of Goldsmith.

Helianthus Maximiliani Schrad. Fulton County, Sept. 17, 1926, No. 43,673. In a prairie habitat in rather sandy soil along the Nickel Plate Railroad about two miles north of Rochester. St. Joseph County, Aug. 24, 1925, No. 42,386. Roadside three and a half miles south of Granger.

Senecio vulgaris L. Delaware County, July 5, 1919. A common weed on a private estate in north Muncie. Wells County, June 22, 1929, No. 47,045. A common weed in some lots about two blocks east of the interurban power house.

Cichorium Intybus forma *alba* Farwell. Allen County, Aug. 22, 1929, No. 47,639. A common weed in dry clay soil along the roadside one mile north and one mile west of Leo. Only a few white-flowered plants were noted among many blue-flowered ones for a distance of nearly a half mile.

Crepis capillaris (L.) Wallr. Wells County, Oct. 28, 1923. Frequent in Fairview Cemetery at Bluffton. The sexton told me at that time that the plant had been there several years. I visited this place late in 1929 and I found that it had spread to all parts of the cemetery.

ENUMERATION OF THE VASCULAR FLORA OF A LIMESTONE AREA OF THE BLOOMINGTON QUADRANGLE, MONROE COUNTY, INDIANA

GLADYS PRICE and WINONA H. WELCH, Indiana University

This list of plants was prepared, during 1927 and 1928, while making ecological studies in an area of four square miles northeast of Bloomington. The specimens upon which the following enumeration is based and the manuscript which includes the data concerning the habitats and the dates and places of collection are deposited in the herbarium of Indiana University.

The enumeration consists of 86 families, 269 genera, and 399 species and varieties. The nomenclature is that found in the seventh edition of Gray's New Manual of Botany.

The authors are indebted to Dr. Paul Weatherwax, to Dr. T. G. Yuncker, and to Mr. C. C. Deam for checking, respectively, the specimens of Gramineae, Cuscuta, and all other doubtful identifications.

Polypodiaceae: *Phegopteris hexagonoptera* (Michx.) Fee; *Adiantum pedatum* L.; *Pteris aquilina* L.; *Asplenium platyneuron* (L.) Oakes; *A. angustifolium* Michx.; *A. acrostichoides* Sw.; *A. Felix-femina* (L.) Bernh.; *Camptosorus rhizophyllus* (L.) Link; *Polystichum acrostichoides* (Michx.) Schott; *Aspidium noveboracense* (L.) Sw.; *A. marginale* (L.) Sw.; *A. Goldianum* Hook.; *A. spinulosum* (O. F. Müller) Sw.; *Cystopteris bulbifera* (L.) Bernh.; *C. fragilis* (L.) Bernh.; *Woodsia obtusa* (Spreng.) Torr.

Ophioglossaceae: *Botrychium obliquum* Muhl.; *B. virginianum* (L.) Sw.

Equisetaceae: *Equisetum arvense* L.

Lycopodiaceae: *Lycopodium complnatum* L., var. *flabelliforme* Fernald.

Pinaceae: *Pinus strobus* L.; *Juniperus virginiana* L.

Typhaceae: *Typha latifolia* L.

Najadaceae: *Potamogeton* sp.

Alismaceae: *Alisma Plantago-aquatica* L.

Gramineae: *Andropogon virginicus* L.; *Digitaria sanguinalis* (L.) Scop.; *Panicum dichotomiflorum* Michx.; *P. hauchucae* Ashe, var. *silvicola* Hitch. & Chase; *Echinochloa crusgalli* (L.) Beauv.; *Setaria glauca* (L.) Beauv.; *Leersia oryzoides* (L.) Sw.; *Muhlenbergia mexicana* (L.) Trin.; *Danthonia spicata* (L.) Beauv.; *Poa pratensis* L.; *Hystrix patula Moench.*

Cyperaceae: *Cyperus strigosus* L., var. *compositus* Britton; *Eleocharis obtusa* (Willd.) Schultes; *Scirpus pedicellatus* Fernald; *Carex picta* Steud.; *C. Frankii* Kunth.

Araceae: *Arisaema triphyllum* (L.) Schott.

Commelinaceae: *Tradescantia pilosa* Lehm.

Juncaceae: *Juncus tenuis* Willd., var. *anthelatus* Wiegand; *J. acuminatus* Michx.

Liliaceae: *Uvularia grandiflora* Sm.; *Allium canadense* L.; *Erythronium americanum* Ker.; *Smilacina racemosa* (L.) Desf.; *Polygonatum biflorum* (Walt.) Ell.; *P. commutatum* (R. & S.) Dietr.; *Trillium sessile* L.; *T.*

recurvatum Beck; *T. nivale* Riddell; *Smilax herbacea* L., var. *pulverulenta* (Michx,) Gray; *S. hispida* Muhl.

Dioscoreaceae: *Dioscorea villosa* L.

Orchidaceae: *Spiranthes gracilis* (Bigel.) Beck; *S. cernua* (L.) Richard, var. *ochroleuca* (Rydb.) Ames; *Aplectrum hyemale* (Muhl.) Torr.

Salicaceae: *Salix nigra* Marsh.; *S. cordata* Muhl.; *Populus grandidentata* Michx.

Juglandaceae: *Juglans cinerea* L.; *J. nigra* L.; *Carya ovata* (Mill.) K. Koch; *C. laciniosa* (Michx. f.) Loud.; *C. glabra* (Mill.) Spach; *C. cordiformis* (Wang.) K. Koch.

Betulaceae: *Ostrya virginiana* (Mill.) K. Koch; *Carpinus caroliniana* Walt.

Fagaceae: *Fagus grandifolia* Ehrh.; *Quercus alba* L.; *Q. macrocarpa* Michx.; *Q. Prinus* L.; *Q. rubra* L.; *Q. coccinea* Muench.; *Q. velutina* Lam.; *Q. Schneckii* Britton. (Identified in Britton and Brown.)

Urticaceae: *Ulmus fulva* Michx.; *U. americana* L.; *Celtic occidentalis* L.; *Maclura pomifera* (Raf.) Schneider; *Morus rubra* L.; *Laportea canadensis* (L.) Gaud.; *Pilea pumila* (L.) Gray; *Parietaria pennsylvanica* Muhl.

Aristolochiaceae: *Asarum canadense* L.; *Aristolochia Serpentaria* L.

Polygonaceae: *Rumex crispus* L.; *R. obusifolius* L.; *R. Acetosella* L.; *Polygonum aviculare* L.; *P. pennsylvanicum* L.; *P. acre* HBK.; *P. Persicaria* L.; *P. virginianum* L.; *P. sagittatum* L.; *P. scandens* L.

Chenopodiaceae: *Chenopodium ambrosioides* L., var. *anthelminticum* (L.) Gray; *C. album* L.

Amaranthaceae: *Amaranthus retroflexus* L.

Phytolaccaceae: *Phytolacca decandra* L.

Illecebraceae: *Anychia polygonoides* Raf.

Caryophyllaceae: *Stellaria pubera* Michx.; *S. media* (L.) Cyrill.; *Cerastium vulgatum* L.; *C. nutans* Raf.; *Silene virginica* L.; *S. stellata* (L.) Ait. f.

Portulacaceae: *Claytonia virginica* L.

Ranunculaceae: *Ranunculus abortivus* L.; *R. recurvatus* Poir.; *R. septentrionalis* Poir.; *Thalictrum diocum* L.; *Anemonella thalictroides* (L.) Spach; *Hepatica acutiloba* DC.; *Anemone virginiana* L.; *Isopyrum biternatum* (Raf.) T. & G.; *Aquilegia canadensis* L.; *Delphinium tricorne* Michx.; *Actea alba* (L.) Mill.; *Hydrastis canadensis* L.

Magnoliaceae: *Liriodendron Tulipifera* L.

Anonaceae: *Asimina triloba* Dunal.

Menispermaceae: *Menispermum canadense* L.

Berberidaceae: *Podophyllum peltatum* L.; *Jeffersonia diphylla* (L.) Pers.

Lauraceae: *Sassafras variifolium* (Salisb.) Ktze.; *Benzoin aestivale* (L.) Nees.

Papaveraceae: *Sanguinaria canadensis* L.; *Stylophorum diphyllum* (Michx.) Nutt.

Fumariaceae: *Dicentra Cucullaria* (L.) Bernh.; *D. canadensis* (Goldie) Walp.

Cruciferae: *Draba verna* L.; *Lepidium* virginicum L.; *Capsella Bursa-pastoris* (L.) Medic.; *Brassica nigra* (L.) Koch; *Sisymbrium officinale* (L.) Scop., var.

leiocarpum DC.; *Iodanthus pinnatifidus* (Michx.) Steud.; *Dentaria laciniata* Muhl.; *Cardamine pennsylvanica* Muhl.; *Arabis laevigata* (Muhl.) Poir.

Crassulaceae: *Penthorum sedoides* L.; *Sedum ternatum* Michx.

Saxifragaceae: *Heuchera americana* L.; *Hydrangea arborescens* L.; *Ribes Cynosbati* L.

Hamamelidaceae: *Hamamelis virginiana* L.; *Liquidambar Styraciflua* L.

Platanaceae: *Plantanus occidentalis* L.

Rosaceae: *Aruncus sylvester* Kosteletzsky; *Pyrus coronaria* L.; *P. Malus* L.; *Amelanchier canadensis* (L.) Medic.; *Crataegus sp.*; *C. punctata* Jacq.; *Fragaria virginiana* Duchesne; *Potentilla monspeliensis* L.; *P. canadensis* L.; *Geum canadense* Jacq.; *Rubus occidentalis* L.; *R. allegheniensis* Porter; *R. villosus* Ait.; *Agrimonia mollis* (T. & G.) Britton; *A. rostellata* Wallr.; *Rosa setigera* Michx.; *R. carolina* L.; *R. humilis* Marsh.; *Prunus serotina* Ehrh.; *P. Mahaleb* L.; *P. americana* Marsh.; *P. Persica* (L.) *Stokes.*

Leguminosae: *Gymnocladus dioica* (L.) Koch; *Gleditsia triacanthos* L.; *Cassia Medsgeri* Shafer; *Cercis canadensis* L.; *Trifolium pratense* L.; *T. repens* L.; *T. hybridum* L.; *Melilotus alba* Desr.; *Robinia Pseudo-Acacia* L.; *Desmodium nudiflorum* (L.) DC.; *D. rotundifolium* (Michx.) DC.; *D. Dillenii* Darl.; *D. paniculatum* (L.) DC.; *Lespedeza procumbens* Michx.; *L. frutescens* (L.) Britton; *L. hirta* (L.) Hornem.; *Strophostyles helvola* (L.) Britton; *Amphicarpa monica* (L.) Ell.

Linaceae: *Linum striatum* Walt.; *L. virginianum* L.

Oxalidaceae: *Oxalis violacea* L.; *O. stricta* L.; *O. corniculata* L.

Geraniaceae: *Geranium maculatum* L.

Rutaceae: *Zanthoxylum americanum* Mill.

Euphorbiaceae: *Acalypha virginica* L.; *Euphorbia Preslii* Guss.

Anacardiaceae: *Rhus glabra* L.; *R. copallina* L.; *R. Toxicodendron* L.

Celastraceae: *Evonymus atropurpureus* Jacq.; *E. obovatus* Nutt.; *Celastrus scandens* L.

Staphyleaceae: *Staphylea trifolia* L .

Aceraceae: *Acer saccharum* Marsh.; *A. saccharum,* var. *nigrum* (Michx. f.) Britton; *A. rubrum* L.; *L. Negundo* L.

Sapindaceae: *Aesculus glabra* Willd.

Balsaminaceae: *Impatiens pallida* Nutt.; *I. biflora* Walt.

Vitaceae: *Psedera quinquefolia* (L.) Greene; *P. vitacea* (Knerr) Greene; *Vitis aestivalis* Michx.

Tiliaceae: *Tilia americana* L.

Malvaceae: *Abutilon Theophrasti* Medic.; *Sida spinosa* L.; *Malva rotundifolia* L.

Hypericaceae: *Hypericum punctatum* Lam.; *H. mutilum* L.

Violaceae: *Hybanthus concolor* (Forster) Spreng.; *Viola papilionacea* Pursh; *V. palmata* L.; *V. sororia* Willd.; *V. pubescens* Ait.; *V. striata* Ait.

Cactaceae: *Opuntia Rafinesquii* Engelm.

Thymelacaceae: *Dirca palustris* L.

Lythraceae: *Cuphea petiolata* (L.) Koehne.

Onagraceae: *Ludvigia palustris* (L.) Ell.; *Oenothera biennis* L.; *Gaura biennis* L.; *Circaea lutetiana* L.

Umbelliferae: *Sanicula canadensis* L.; *S. trifoliata* Bicknell; *Erigenia bulbosa* (Michx.) Nutt.; *Osmorhiza Claytoni* (Michx.) Clarke; *Cryptotaenia canadensis* (L.) DC.; *Thaspium aureum* Nutt.; *T. barbinode* (Mich.) Nutt.; *Pastinaca sativa* L.; *Daucus Carota* L.

Cornaceae: *Cornus florida* L.; *C. alternifolia* L. f.; *Nyssa sylvatica* Marsh.

Ericaceae: *Chimaphila maculata* (L.) Pursh; *Monotropa uniflora* L.; *Epigaea repens* L.; *Gaylussacia baccata* (Wang.) C. Koch; *Vaccinium vacillans* Kalm.

Primulaceae: *Samolus floribundus* HBK.; *Lysimachia Nummularia* L., *Steironema lanceolatum* (Walt.) Gray.

Oleaceae: *Fraxinus americana* L.; *F. pennsylvanica* Marsh.; *F. quadrangulata* Michx.

Apocynaceae: *Apocynum cannabinum* L.

Asclepiadaceae: *Asclepias incarnata* L.; *A. syriaca* L.

Convolvulaceae: *Ipomoea hederacea* Jacq.; *Cuscuta arvensis* Beyrich; *C. Gronovii* Willd.

Polemoniaceae: *Phlox divaricata* L.; *Polemonium reptans* L.

Hydrophyllaceae: *Hydrophyllum canadense* L.; *H. appendiculatum* Michx.; *Phacelia bipinnatifida* Michx.

Boraginaceae: *Cynoglossum officinale* L.; *C. virginianum* L.; *Lappula virginiana* (L.) Greene.

Verbenaceae: *Verbena urticaefolia* L.

Labiatae: *Teucrium canadense* L. *Isanthus brachiatus* (L.) BSP.; *Scutellaria lateriflora* L.; *S. versicolor* Nutt.; *S. canescens* Nutt.; *Marrubium vulgare* L.; *Agastache nepetoides* (L.) Ktze.; *Nepeta Cataria* L.; *N. hederacea* (L.) Trevisan; *Prunella vulgaris* L.; *Synandra hispidula* (Michx.) Britton; *Leonurus Cardiaca* L.; *Monarda fistulosa* L.; *Blephilia ciliata* (L:) Raf.; *B. hirsuta* (Pursh) Benth.; *Hedeoma pulegioides* (L.) Pers.; *Lycopus uniflorus* Michx.; *L. americanus* Muhl.; *Mentha spicata* L.; *Collinsonia canadensis* L.

Solanaceae: *Solanum nigrum* L.; *S. carolinense* L.; *Physalis pubescens* L.; *P. subglabrata* Mackenzie & Bush; *Datura Stramonium* L.; *D. Tatula* L.

Scrophulariaceae: *Verbascum Thapsus* L.; *V. Blattaria* L.; *Linaria vulgaris* Hill; *Scrophularia marilandica* L.; *Pentstemon laevigatus* Ait., var. *Digitalis* (Sweet) Gray; *Mimulus alatus* Ait.; *Conobea multifida* (Michx.) Benth.; *Veronica serpyllifolia* L.; *Seymeria macrophylla* Nutt.; *Gerardia virginica* (L.) BSP.; *G. tenuifolia* Vahl; *Pedicularis canadensis* L.

Orobanchaceae: *Epifagus virginiana* (L.) Bart; *Conopholis americana* (L. f.) Wallr.; *Orobanche uniflora* L.

Bignoniaceae: *Tecoma radicans* (L.) Juss.

Acanthaceae: *Ruellia strepens* L.

Phrymaceae: *Phryma Leptostachya* L.

Plantaginaceae: *Plantago Rugelii* Dene.; *P. lanceolata* L.; *P. aristata* Michx.; *P. virginica* L.

Rubiaceae: *Galium Aparine* L.; *G. circaezans* Michx.; *G. concinnum* T. & G.; *G. triflorum* Michx.; *Mitchella repens* L.; *Cephalanthus occidentalis* L.; *Houstonia purpurea* L.

Caprifoliaceae: *Lonicera japonica* Thunb.; *Symphoricarpos orbiculatus* Moench; *Triosteum aurantiacum* Bicknell; *Viburnum acerifolium* L.; *V. prunifolium* L.; *Sambucus canadensis* L.

Valerianaceae: *Valeriana pauciflora* Michx.

Dipsacaceae: *Dipsacus sylvestris* Huds.

Cucurbitaceae: *Echinocystis lobata* (Michx.) T. & G.

Campanulaceae: *Specularia perfoliata* (L.) DC.; *Campanula americana* L.

Lobeliaceae: *Lobelia siphilitica* L.; *L. inflata* L.

Compositae: *Vernonia altissima* Nutt.; *Eupatorium purpureum* L; *E. serotinum* Michx.; *E. perfoliatum* L.; *E. urticaefolium* Reichard; *E. coelestinum* L.; *Solidago caesia* L.; *S. latifolia* L.; *S. nemoralis* Ait.; *S. altissima* L.; *S. graminifolia* (L.) Salisb.; *Brachychaeta sphacelata* (Raf.) Britton; *Aster azureus* Lindl.; *A. Shortii* Lindl.; *A. cordifolius* L.; *A. ericoides* L., var. *villosus* T. & G.; *A. dumosus* L.; *A. lateriflorus* (L.) Britton, var. *hirsuticaulis* (Lindl.) Porter; *A. Tradescanti* L.; *Erigeron annuus* (L.) Pers.; *E. canadensis* L.; *Antennaria plantaginifolia* (L.) Richards.; *Gnaphalium polycephalum* Michx.; *Polymnia canadensis* L.; *Ambrosia trifida* L.; *A. artemisiifolia* L.; *Xanthium canadense* Mill.; *Heliopsis helianthoides* (L.) Sweet; *H. scabra Dunal*; *Eclipta alba* (L.) Hassk.; *Helianthus tuberosus* L.; *Actinomeris alternifolia* (L.) DC.; *Bidens frondosa* L.; *B. comosa* (Gray) Wiegand; *B. bipinnata* L.; *Achillea Millefolium* L.; *Anthemis Cotula* L.; *Chrysanthemum Leucanthemum* L.; *Tanacetum vulgare* L.; *Erechtites hieracifolia* (L) Raf.; *Cacalia reniformis* Muhl.; *Senecio obovatus* Muhl.; *S. aureus* L.; *Arctium minus* Bernh.; *Cirsium lanceolatum* (L.) Hill; *C. altissimum* (L.) Spreng.; *Krigia amplexicaulis* Nutt.; *Taraxacum officinale* Weber; *Sonchus asper* (L.) Hill; *Lactuca scariola* L.; *L. sagittifolia* Ell.; *L. floridana* (L.) *Gaertn.*; *L. spicata* (Lam.) Hitchc.; *Prenanthes altissima* L.; *Hieracium paniculatum* L.; *H. scabrum* Michx.; *H. Gronovii* L.

SOME FLOWERING PLANTS COLLECTED IN PARKE COUNTY, INDIANA

Rexford F. Daubenmire, Butler University

The following is a list of flowering plants collected by the writer in Parke County, Indiana, during the summer of 1929. A specimen of each species has been deposited in the herbarium of Butler University, Indianapolis, Indiana. Although some of these species have been previously reported from this county, no record has come to the attention of the writer of specimens being placed in Indiana herbaria. An asterisk after the name indicates that the species has been previously reported. The nomenclature used is that of Gray's Manuel, 7th edition.

The writer wishes to express appreciation for the coöperation of Mr. S. R. Esten of the Department of Conservation for the permission to collect in Turkey Run State Park.

Abutilon theophrasti, Acorus calamus, Amelanchier canadensis, Anemone virginiana, Aralia racemosa, Blephilia hirsuta, Campanula americana, Carpinus caroliniana, Cassia marylandica, Celtis occidentalis*, Circaea lutetiana, Cornus florida, Corylus americana, Cryptotaenia canadenis*, Echinocystis lobata*, Epipactis pubescens*, Erigeron annuus*, Eupatorium perfoliatum, E. purpureum*, E. urticaefolium, Galium circaezans, G. concinnum, Gerardia skineriana, Hedeoma pulegioides, Hieraceum longipilum, Houstonia lanceolata, Hydrangea arborescens, Hypericum ascyron, H. gymnanthemum, Leonurus cardiaca, Linaria vulgaris, Lobelia inflata, L. siphilitica*, Mimulus alatus*, Osmorhiza claytoni*, Oxalis corniculata*, Parnassia caroliniana, Penthorum sedioides, Pentstemon hirsutus, Phryma leptostachya, Pilea pumila*, Plantago aristata, Pogonia trianthophora*, Polygala sanguinea, Polygonum scandens, Populus grandidentata, Prunella vulgaris, Pycnanthemum pilosum, Quercus velutina, Ranunculus hispidus, Rudbeckia hirta, Rumex crispus*, Sabatia angularis, Salix longifolia*, Sambucus canadensis*, Sassafras variifolium, Scutelaria canescens, Solidago altissima, S. nemoralis, S. ulmifolia, Taxus canadensis*, Tilia americana*, Verbena urticaefolia*.*

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NEW PARASITIC FUNGI OF MONTGOMERY COUNTY[1]

H. J. Lee[2]

PHYCOMYCETES

Phytophthora infestans (Mont.) DeBary on *Solanum tuberosum* Sept. 21, 1928. Market garden just northwest of Crawfordsville. Usually not occurring here at all.

Bremia lactuca Regel on *Lactuca sativa* Oct. 19, 1927.

ASCOMYCETES

Sclerotinia libertiana Fcl. on *Daucus carota* March, 1929.

Sclerotinia erythronii Whetzel on *Erythronium americanum* April 22, 1927. Wabash College Campus; also many other places in the county. Very plentiful some years. See Whetzel: North American Species of Sclerotinia, I, in Mycologia, Vol. XVIII, No. 5, Sept.-Oct., 1926, pp. 224-235.

Phyllactinia corylea (Pers.) Karst. on *Quercus rubra* Oct. 17, 1927.

Microsphaera alni (Wal.) Salm. on *Viburnum prunifolium* Oct. 11, 1927.

* *Hypoxylon morsei* B. & C. on *Rhus vernix* Spring, 1929. "Cranberry Bog," near Elmdale. Parasitism doubtful; however, the cortex of the substratum seemed green.

BASIDIOMYCETES

Ustilago heufleri Fcl. on *Erythronium americanum* April 30, 1929. Wabash College Campus.

Cintractia luzulae (Sacc.) Clinton on *Luzula campestris* April 30, 1929. Covington Hill, northwest of Crawfordsville. See North American Flora, Vol. 7, Part 1, Oct. 4, 1906.

* *Uredinopsis pteridis* Diet. & Holw. on *Pteris aquilina* Aug. 25, 1927. Bluff along Sugar Creek, south of the mouth of Offield Creek.

† *Phragmidium subcorticium* (Schrank) Wint. on cult. rose (yellow) May 25, 1929. 506 S. Grant St., Crawfordsville.

Puccinia malvacearum Mont. on *Malva rotundifolia* Oct. 18, 1927.

Puccinia triglodytes Lindi. on *Galium triflorum* Aug. 25, 1927. Woods along Sugar Creek, south of the mouth of Offield Creek.

FUNGI IMPERFECTI

Macrosporium cucumerinum E. & E. on *Cucumeris melo* Sept. 14, 1928.

* *Sphaerographium fraxini* (Peck) Sacc. on *Fraxinus* sp. Spring, 1929. Binford's Woods, northeast of Crawfordsville.

Heterosporium gracile (Wal.) Sacc. on *Iris germanica* Sept. 14, 1928.

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[1] These species are in addition to those listed by H. W. and P. J. Anderson, in the Proceedings of the Ind. Academy of Science, 1919, pp. 175-222.

[2] Those marked * were collected by Prof. A. R. Bechtel, Wabash College; that marked † was collected by A. W. Bayer; and the remainder were collected by the writer.

THE DECOMPOSITION OF CELLULOSE IN NATURE*

P. A. Tetrault, Purdue University

The breaking down of cellulose in nature is apparently a function of the lower forms of life. Protozoa, fungi and bacteria are the most active organisms in this respect. To be sure the higher forms of animal life use cellulose for food. This is especially true of the ruminants. This utilization, however, seems to be dependant on the presence of some bacteria or protozoa in the alimentary tract. According to Yonge (1925), cellulose has never been demonstrated in the vertebrates. On the other hand, many organisms capable of digesting cellulose have been found in both higher and lower forms of life.

Khouvine (1922) claimed to have isolated an anaerobic bacterium from the intestinal tract of man. Zuntz (1892) stated that in the case of the horse the cellulose passed to the caecum and was there digested by microorganisms. Hopffe (1919) made a bacteriological analysis of the rumen of cattle and isolated 33 organisms. Of this number only a few of the common soil forms had the ability to digest cellulose. This ability was soon lost after transferring to a new medium. She believed that protozoa were necessary for cellulose digestion in cattle. Tappeiner (1880) said that cellulose was digested in the first three stomachs of ruminants. He compared this digestion with that of sugars and starches and pointed out that if such carbohydrates were present the cellulose would not be attacked. The presence of large amounts of albuminoids seemed to favor the digestion of cellulose even in the presence of sugars. Shirokikh (1900) said that in sheep one-third of the cellulose was digested in the paunch. The percentage of cellulose to the total bulk was very low in the small intestines but increased before the cellulose was finally excreted. This same author stated that in the case of the rabbit, the digestion took place in the blind intestine. Like sheep, goats are able to digest large amounts of cellulose. Edin (1920) reported between 83 and 98 per cent of the cellulose ingested as food by these animals as digested.

Unlike the mammals the birds do not seem to have the ability to digest cellulose. The rapidity with which digestion takes place would preclude any possibility of bacterial action. Radeff (1928) reported on his experiment with chickens. He found that raw fiber as found in barely could not be digested, while five per cent of wheat fiber, seven per cent of oat fiber and seventeen per cent of cracked corn could be. As for the mammals, this digestion occurred in the caecum.

Cleveland (1925), in a series of papers covering his researches with termites, brought to light a very interesting type of symbiosis. These insects were able to utilize pure cellulose for food provided certain protozoa were present in the intestinal tract. By starvation, oxidation and change of temperature, the author was able to free the intestinal tract of all protozoa. Under these conditions, the termites could live for only a short time on cellulose alone as food. If fed fungous-digested cellulose they carried on a normal existence. With the protozoa present the insects were able to survive eighteen months or more on a diet of pure cellulose. No bacteria were mentioned. Where the termites got their nitrogen

*Part of a thesis submitted at the University of Wisconsin in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

was not explained. The author, however, did mention the possibility of nitrogen fixation although he was not able to demonstrate the process.

There are a few crustacea that can digest cellulose. Biederman and Moritz (1898) showed that the fresh water cray-fish was able to dissolve reserve cellulose from the endosperm of seeds. They further stated that the alimentary tract of *Helix* contained a fluid which would attach hemicelluloses but not celluloses. Seillière (1906) showed that the digestive fluid of *Helix* acts on cotton fibers to a very slight extent; much more rapidly if the cotton was finely divided. Yonge (1925) found that the Teredinidae could digest cellulose. The material was stored in the caecum and was there slowly digested. Eighty per cent of the cellulose was changed in passing through *Teredo*.

The fungi are very active in decomposing cellulose. Kellerman and associates (1913), Daszewska (1912) and others stated that they were more active than bacteria. The higher fungi do not lend themselves well to experimentation. Some doubt is expressed as to whether they have the property of digesting cellulose that the lower forms have. Schmitz (1919) concluded that the rate of decomposition of wood by *Fomes*, *Polystictus* and *Lenzites* was greatly increased by the presence of saprophytes. He was, however, unable to isolate any cellulose decomposing bacteria.

Kellerman (1913) demonstrated the presence of an active cytase in *Penicillium pinophilum*. The author, no doubt, would now term his enzyme cellulase to conform with present usage. His method was to inoculate either spores or pieces of mycelium on the surface of a tube of cellulose agar. After from 20 to 40 days the fungus had developed an enzyme that decomposed the cellulose in the tube below the growth. To demonstrate the presence of the enzyme, he transferred slices of this agar, removed from the tube aseptically, to plates of cellulose agar. The slice removed from below the cleared zone showed no decomposition of cellulose when transferred to agar while the three taken in the zone, but below the growth, showed decomposition but no growth. Scales (1915) did the same with the species of *Aspergillus*.

A number of workers report the isolation of fungi capable of destroying cellulose. Scales (1915) found 32 out of 40 species of *Aspergillus* and *Penicillium* studied, capable of destroying cellulose. Hopffe (1919) isolated an aspergillus from the digestive tract of cattle which could digest cellulose at 35 to 37°C. Mutterlein (1913) did a very extensive piece of work on cellulose decomposition in soils and manures. He reported the isolation of 21 different organisms capable of destroying this material. Of this number 20 were fungi and actinomyces. Heukelekian (1928), Waksman (1926) and Dubos (1928) all reported the isolation of fungi active in cellulose destruction.

The actinomyces are less able to use cellulose than either the fungi or the bacteria. Nevertheless, in dry soils, according to Dubos (1928) they were quite active. Actinomyces capable of digesting cellulose have been isolated by Mutterlein (1913), Krainsky (1913), Dubos (1928) and many others. Waksman and Skinner (1926) claimed that these organisms were limited in their action to the by-products of the cellulose fermentation.

Cellulose Decomposition by Bacteria. The bacterial decompostion of cellulose seems to have occupied the attention of workers much more than that brought about by either actinomyces or fungi. As early as 1850 Mitscherlich reported on the decomposition of cellulose by bacteria. In a potato culture he noticed that the walls of the parenchyma cells were decomposed. He filtered his

culture and introduced new slices of potato. These were decomposed more readily than the first. Many vibrios were found in the culture and to these he attributed the digestion. Trecul (1865) described rod forms which appeared in decomposing plant cells. These had the property of staining blue with iodine. To these he gave the name "Amylobacter." It is this group of organisms that played the leading rôle in the early history of the study of cellulose decomposition.

Popoff (1875) was the first to study the fermentation of cellulose from a bio-chemical angle. He claimed that the destruction of Swedish filter paper took place with the evolution of CO_2, CH_4 and H_2. The carbon dioxide and methane were evolved during the fermentation of cellulose while the H_2 resulted from the secondary fermentation; that of butyric acid.

Van Tieghem published the results of his studies of cellulose fermentation in 1879. He claimed that *B. amylobacter* was the true causative agent. His organism could use sugar as readily as cellulose, but if the two were present, cellulose was not attacked. The enzyme bringing about the change was not extra-cellular and was formed only when the organism was stimulated by the cellulose. This seems to be the first mention of the nature of the enzyme. Unfortunately Van Tieghem worked with plant cells rather than with pure cellulose. Further his cultures were not pure, as is shown by the work of Omeliansky in 1895.

Hoppe-Seyler (1886) observed anaerobic fermentation of cellulose, using sewage mud as inoculum. His experiments lasted for four years at room temperature. The bacteria described cannot be distinguished from Van Tieghem's amylobacter. The fermentaion according to this author, was divided into two phases: *first*, the hydrolytic phase where cellulose was broken down to a monosaccharide,

$$C_6H_{10}O_5+H_2O=C_6H_{12}O_6;$$

second, the oxidation-reduction phase which took into account the breaking down of the C_6 sugar to methane and carbon dioxide,

$$C_6H_{12}O_6=3CO_2+3CH_4.$$

He was unable to detect any volatile acids and therefore, claimed that the views of van Tieghem were incorrect. He stated, however, that there was a possibility that such acids might be formed as intermediate products.

Symbiosis as a factor in tearing down cellulose was first worked out by Van Senus in 1890. He worked with organisms from the blind intestine of rabbits. This part of the alimentary tract of the rabbit, he described as being filled to about half its capacity with organisms resembling *B. amylobacter* of van Tieghem. This large bacillus and a small one which he was able to isolate from the same source, caused the decomposition of cellulose. Each one separately had no effect on the carbohydrate. One organism made the harmful product of fermentation harmless for the other organism; a statement difficult to understand if neither has any effect by itself. The process he classified as anaerobic. His views on the mechanism of fermentation were at least novel. The products he gave as H_2, CO_2, acetic and butyric acids. Butyric acid came from the protein decomposition. He did not believe the production of CH_4 to be an independant process. Acetic acid was reduced by the hydrogen present successively to aldehyde, alcohol, ethane and methane. Where no other easily reducible substance was present CH_4 and CO_2 only were found. Thus he explained Hoppe-Seyler's results.

Omeliansky in a series of papers extending over a period of years gave the results of his efforts to solve the problem of anaerobic decomposition of cellulose.

According to this author, *B. amylobacter* was not the causative agent. The true agent was a short bacillus that elongated before sporulation. It did not stain blue with iodine and therefore, could not be included in the amylobacter group. The anaerobic destruction of cellulose was of two types, one he called the methane fermentation and the other the hydrogen fermentation. Omeliansky's work may be criticised on the basis of his methods. For transfer he used pieces of filter paper from fermenting flasks. He claimed that in a few transfers, because of the enrichment medium, he soon obtained a pure culture. The purity was judged by microscopic observation only. He made several attempts at isolation. He obtained growth on potato in the form of small yellow colonies. These, however, failed to cause fermentation when transferred to his enrichment medium. Concerning these colonies he says: "cependant, les caractères morphologiques des bacilles ayant poussé sur pomme de terre, aussi bien que le fait d'avoir fait fermenter le papier, ne laissent aucum doute que nous avons bien réussi a obtenir des colonies du ferment*." Other than this potato experiment, all attempts at growth on any solid medium failed.

His organism being a spore former, it was thought that the contaminant could be separated by heat. Boiling temperature, however, failed to give the desired results. Fractional heating was tried but with the same negative results. Dilution methods were attempted but to no avail. The use of carbohydrates other than cellulose gave no results. He explained the failure of his dilution method by saying that a large inoculum is necessary. Failing in all attempts to separate what he believed to be two or more organisms he tried to explain their presence on the basis of symbiosis. He tried various experiments of mixing organisms but he was never able to get the typical fermentation.

Omeliansky's researches, although, leaving much to be desired as to purity of cultures, were accepted as rather conclusive evidence of the presence of two types of cellulose fermentation. It was not until seventeen years after his first report appeared that his conclusions were questioned.

Kellerman and McBeth (1912) isolated from Omeliansky's hydrogen culture, two cellulose destroyers and five contaminants. From his methane culture they isolated one cellulose fermenter and two contaminants. The three cellulose fermenters, they named *B. rossica*, *B. amylolyticus* and *Bact. flavigens*. All of these organisms were morphologically different from Omeliansky's hydrogen and methane organisms. They grew well on ordinary gelatine media, although, continued growth resulted in loss of cellulose fermenting properties. They did not produce gas. For isolations, these workers used agar plates. Their medium consisted of a minerial solution to which was added cellulose, agar and $CaCO_3$. The colonies developed with the characteristic halo. When transferred to liquid cellulose media they failed to digest cellulose. The method used and the results obtained led Omeliansky to criticise the work of the two American workers on the basis of faulty observations. It was claimed that the clear zones were not caused by the digestion of the cellulose but by the action of acids on the $CaCO_3$. The acids might have arisen from the decomposition of organic substances in tap water; from extraction materials from the agar; or from products of partial hydrolysis of agar in the presence of mineral salts. The fact that fermentation was lacking in liquid cultures when a colony was transferred, led Pringsheim (1923) to criticise the work stating that pure cultures could not be obtained by the method employed. The organisms transferred from the agar plate were not

*Archives des Sciences Biologiques, 7:724, 1899

cellulose decomposers but contaminants, he stated; therefore, the failure of the liquid cultures. Löhnis and Lochhead (1913) corroborated the work of Kellerman and McBeth and showed very conclusively that the clear areas on the plate were zones of digested cellulose. Their method was to pour HCl over the plate in question, to dissolve out the $CaCO_3$. With the plate transparent the disappearance of the cellulose could very easily be detected.

Aerobic cellulose decomposition was first studied in 1904. Van Iterson found that when a medium consisting of paper and mineral salts was distributed in shallow layers and inoculated with ditch mud, an energetic fermentation followed. His experiments were carried out at a temperature between 25° and 35°C. In addition to the various contaminating forms encountered in mixed cultures he noticed the presence of two forms; one a small rod and the other a large micrococcus. The rod, he named *B. ferrugineus*. The micrococcus, he regarded as an organism that facilitated the decomposition of cellulose but did not play an active part itself. All attempts to digest cellulose with what he claimed to be pure cultures, failed.

Löhnis and Lochhead (1913) isolated aerobic cellulose fermenters using the Kellerman method. Contrary to Kellerman's conclusions, however, the authors were able to get an active fermentation in liquid media inoculated with colonies from the plate.* They raised the question of purity of their cultures as they observed spherical as well as rod shaped cells. They hinted at symbiosis but carried out no experiments to prove or disprove this. Löhnis suggested that the organism might have had a life cycle and that these different morphological forms might have been stages in this cycle. Their findings, according to the authors, check up pretty closely with those of Hutchinson and Clayton (1919).

McBeth and Scales (1913) isolated 15 cellulose destroying bacteria from soils. All were facultative but destroyed more cellulose under aerobic conditions. Transferred from the agar plate to liquid media, they all lost the property of using this material. All of the organisms grew on gelatin, although, this was not a good medium for isolation. No gas was given off during the process. They explained the presence of CO_2 and CH_4 on the basis of a secondary fermentation of by-products. Many organisms that could use these by-products were present in the soil, according to the authors, and a mixed culture would give gas while the pure culture would not; if their contention were correct. They carried out experiments to show this. Two flasks that had undergone a typical fermentation were used. One was inoculated with soil while the other was not. The first showed gas formation in 48 hours and continued to produce gas for two to four weeks. One hundred c.c. of gas were collected and analysed. It proved to be CO_2 and H_2. The second flask never showed any gassing. In no case did they find CH_4 in any of the filter paper fermentations. Only when large amounts of nitrogenous matter were present were they able to show the presence of this gas. Attempts were made to isolate organisms capable of giving off gas when associated with cellulose fermenters. In no case were they successful, although, they did get organisms capable of fermenting sugars with gas formation. They stated that the chief by-products were acetic and formic acids with no trace of aldehydes, ketones, alcohols or carbohydrates capable of reducing Fehling's solution.

Hutchinson and Clayton (1919) reported the presence of an organism capable of breaking down cellulose in Rothamstead soil. Morphologically it

*Private correspondence.

presented many characteristics of the Spirochaetoideae and the name *Sp. cytophaga* was suggested. In many respects their organism answers to the description given by van Iterson for his so-called mixed culture. According to the authors, the organism passes through a number of phases which terminate with the production of a "sporoid"—the micrococcus of van Iterson. This "sporoid" differs materially from the true spore of the bacterial cell. On germination it gives rise to a flexible form, therefore, the genus *Spirochaeta*. The organism is aerobic; its optimum temperature around 30°C. All phases are killed by a temperature of 60°C. in 10 minutes. It is very limited in its energy source, being able to use only cellulose. It does not grow well on agar. The authors used mineral salts in tubes to which they added the filter paper in strips, allowing the ends to protrude above the liquid, thus making for better aerobic conditions. Unfortunately, according to Löhnis, the authors' cultures were lost during the war as were the cultures of Löhnis and Lochhead*. From the descriptions it seems that the two organisms belong to the same group if they are not identical. Löhnis' suggestion and Hutchinson and Clayton's statement that the organism goes through a life cycle are probably correct. Further work, however, will be necessary to prove this point.

A number of workers have attempted to show that the process is a symbiotic one. Groenewege (1920) claimed that the process was one of denitrification involving the interaction of two groups of organisms. One group decomposed cellulose while the other reduced the nitrates. He isolated five organisms: *Bact. cella-resolvens alpha, beta* and *gamma* belonging to the cellulose decomposing group and *Bact. opalescens* and *Bact. viscosum* belonging to the denitrifying group. C. M. Hutchinson (1923) reported the isolation of a specific aerobic cellulose dissolving organism and added that the decomposition could be accomplished only through symbiosis with other soil forms, which he does not name. Aoi and Orikura (1928) isolated what they termed the contaminating organism but were unsuccessful in isolating the cellulose decomposer.

Dubos published his results on aerobic cellulose decomposition in 1928. He isolated a number of pure cultures which he placed in three physiological groups as follows: (a) strict aerobes, using only cellulose for carbon; (b) strict aerobes, cellulose decomposers, able to grow on starch but not on nutrient agar; (c) facultative anaerobes, cellulose decomposers which grow well on ordinary media.

Winogradsky (1928) states that anaerobic cellulose decomposition is of minor importance in cultivated soils. He describes three types of aerobic cellulose destroyers:

1. Thin vibrio, spreads rapidly on paper and produces a pale yellow tint. The fibers are lined both externally and along the walls of the lumen with vibrios. The yellowing increases with age. The process seems to stop half way, as many of the fibers are untouched. After three or four weeks the vibrios are autolysed.

2. Decomposition proceeds further, up to 80 per cent. The group is not described.

3. Cytophaga group. These produce colonies and transform the paper to a thick jelly. The pigment is egg yolk yellow, orange or rose according to species. The action is slower than that of the first two groups but much more complete.

In a later publication (1929) Winogradsky goes into further detail regarding

*In a private correspondence, Bunker states that Hutchinson and Clayton's cultures still exist.

the study and classification of the aerobic cellulose decomposers. His method involved the use of silica gel and filter paper. Liquid cultures were never used. Particles of soil were placed on the sterile piece of filter paper on the gel and the plates were incubated at 30°C. After a few days the characteristic color developed and transfers were made either with a straight platinum wire or with a piece of glass tubing drawn out to a very fine point. The colors developed were so characteristic that he claimed they were sufficient to identify the organism. The colors included the various shades of yellow, brown, rose and green. He does not believe in the dilution method for isolation purposes for these groups, due to the fact that the organisms adhere to the fibers and are not dislodged. He describes his method of transfer as follows: "on ne faisait que toucher aussi légèrement et rapidement que possible avec le bout d'un fil de verre capillaire un point choisi et soumis a l'examen microscopique, puis de la même manière le rond neuf*." The question might well be asked whether the author considers that the method described would dislodge more organisms than the vigorous shaking in a dilution bottle? It would seem that if the organisms are so loosely attached as to be removed by a light touch of the wire they would most certainly be removed by shaking. In the case of the *Cytophagas* he does not agree with Hutchinson and Clayton as regards the relationship of the "sporoids." He believes they are a different organism. Still, he says that when they do appear, he is not able to separate the two. He is uncertain about the motility of this group, suggesting that if there is any motility it is of the crawling kind; and he mentions seeing haustoria like appendages, but so minute that he is not ready to affirm their presence. The culture soon autolyses and nothing but round bodies remain which do not stain well and cannot develop into the rod again. He has observed small round bodies which he likens to arthrospores and supposes that reproduction may be carried on by them.

The three groups are classified as:

1. *Cytophaga*, long, flexible filaments, pointed at each end. Motility questionable. Very specific in that they can use nothing but cellulose for carbon. Colors the paper egg yolk yellow, orange, rose, brick red, etc. No spores. He studied four species.

2. *Cellvibrio*, long rods, rounded ends. Actively motile, having only one flagellum. Not as specific as the cytophagas. Produces yellow to cream colored pigment, very diffuse and spreading rapidly over the gel. No spores. Two species studied.

3. *Cellfalcicula*, sickle shaped with pointed ends. Very motile, only one flagellum. Appears to be specific as regards cellulose. Produces greenish tints. No spores. Three species studied.

The author claims that in all cases the cellulose is changed to oxycellulose. He was never able to detect any volatile products.

Thermophilic Decomposition. The first mention of cellulose decomposition at temperatures above 40°C was made by MacFayden and Blaxall in 1899. Soil was added to a nutrient solution and incubated at 60°C. The paper contained in the medium was destroyed in 10 to 14 days. Bacilli as well as many spores were detected in the culture. Zoögloea enclosing many small bacteria were likewise observed. No reducing sugars were found. Their products were

*Ann. Inst. Pasteur, 43:584, 1929.

acetic acid, butyric acid and furfurol. They stated that the action seemed to be symbiotic.

Primm (1913) reported the isolation of pure cultures of thermophilic cellulose fermenters. Unfortunately there is nothing left by which his claim may be proved or disproved. Other than a note and two photographs in a bulletin issued by the Wisconsin Experiment Station, no record of his work seems to exist. In this same year, Kroulik (1913) isolated four cellulose decomposers, two aerobic and two anaerobic, all thermophiles. Three of these were plectridia while the fourth produced equatorial spores. The aerobic organisms did not ferment cellulose after growing on agar while the anaerobes did not grow on solid media. He believed, with Omeliansky, that heavy transfers were necessary. He also considered symbiosis an important factor in the process but was unable to demonstrate it. Grieg-Smith (1921) described a large bacillus with terminal spores as responsible for the thermophilic fermentation of tan-bark.

Pringsheim (1912) established the fact that the fermentation of cellulose passed through the cellobiose and dextrose stages. By using toluol he was able to arrest the fermentation and detect the presence of these carbohydrates. His work was carried out at 60°C. The author further demonstrated that the enzymes did not pass through a Berkefeld filter. The filtrate of an active culture failed to show any decomposition of cellulose when added to this material. He made the statement that the enzyme was intracellular and the organism producing it could be stimulated to its elaboration only by contact with a piece of cellulose. This is essentially what was voiced some years before by van Tieghem. Löhnis points to the clear zone around the colony as proof of the solubility of the enzyme. Kellerman showed the enzyme, in the case of fungi, to be extracellular. Grownwege did the same with the enzyme of bacteria.

Khouvine (1923) reported on her investigations of the digestion of cellulose by the intestinal flora of man. After testing a number of media she limited herself to the use of a substrate consisting of potassium phosphate, sodium chloride, peptone and tap water. A culture was finally enriched that attacked filter paper rather slowly and in spots. Microscopically the spots appeared to contain a large rod, a small rod and a coccus. All methods of dilution or plating failed to separate these, so she picked out a few fibers of the paper and after several washings in physiological salt solution, she claimed that the culture was pure. The cellulose organisms, she reasoned, would adhere to the fiber while the contaminants would be washed away. Fermentation in pure culture was very slow. Her best and most rapid decomposition was obtained when an extract of fecal matter was added. Large inoculations were apparently needed to start the fermentation. She describes the organism, *B. cellulose dissolvens* as a single rod, 2 x 0.4 microns, elongating to 12 microns just before sporulation. The spores are oval and terminal. The organism is gram negative and stains well with anilin dyes. It is a strict anaerobe and does not grow where there is an atmosphere with an O_2 tension of more than 12 mm. of mercury. It grows well in an atmosphere of nitrogen, CO_2, or hydrogen. The spores resist a temperature of 100°C. for 45 to 50 minutes. The optimum for the fermentation is between 35 and 51°C. The organism will survive a temperature of 67°C. indefinitely but will not ferment cellulose. The minimum for fermentation is 33°C. It does not grow on ordinary culture media, and does not ferment carbohydrates other than cellulose. The products of fermentation are CO_2, H_2, acetic and lactic acids, traces of alcohol and pigment. The composition of the pigment is not known. Like Pringsheim and others, she stated that the enzyme concerned was an endo-enzyme.

The work of Viljoen, Fred and Peterson on the isolation of *Cl. thermocellum* and the fermentation of cellulose by this organism was reported in 1926. They used horse manure as the source of inoculating material, and a temperature of 65°C. H_2S was very abundant in cultures made from the first five enrichment transfers. After this the gas was no longer noticeable. The characteristic fermentation with the formation of a "head" and pigment, resulted. When manure was used for inoculum the fermentation lasted for 10 to 14 days. The fermentation in the later transfers lasted only 6 to 8 days. The culture was subjected to a temperature of 118°C. for 25 minutes. At this point the culture was considered pure but growth on solid media was resorted to as a final proof. All attempts to grow the organism on a plate resulted in failures. The culture finally called pure was taken from a shake tube in cellulose agar of a dilution of 1-10,000. A gas bubble formed in the agar and this was removed aseptically and placed in a tube of cellulose medium. The characteristic fermentation resulted. Here again, the failure of earlier workers with the plate method was cited and encouragement was apparently taken from this failure for "it is suggested that some highly oxidizable component is lost during the plating process" and the relation of the organism to solid media was forgotten with that statement. The organism described is a long rod with oval spores and peritrichous flagella. It is gram negative, grows well in nutrient broth, on agar and potato. Many of the sugars are fermented. The products of fermentation are CO_2, H_2, acetic acid, butyric acid and ethyl alcohol.

Thaysen and Bunker (1927) commenting on the work of the above authors have the following to say: "Though the authors mention in this second paper that they have succeeded in isolating the type in pure culture, it is very questionable whether independant investigation would confirm this since Viljoen, Fred and Peterson obtained the culture they describe as pure, from a dilution containing as much as 1-10,000 part crude culture and from this dilution in cellulose agar they isolated, not one well circumscribed colony, but were content to employ as inoculant for their pure cultures, a part of this agar medium containing a gas bubble*." Coolhaas (1928) goes a little further. After describing the method used he says "Versuche von Fred, Peterson und Viljoen nichts beweisen" **. Other than the criticisms cited it seems that the fact that results are not consistent; that growth occurs in dilutions beyond the last giving active fermentation; and the fact that it cannot be transferred from solid media and give fermentation; are very good reasons for considering the culture as impure. Peterson, Fred and Marten (1926) found that the by-products of sugar fermentations are quite different from the by-products obtained from cellulose.

Cl. thermocellum and *B. cellulose dissolvens* are the only two thermophilic cellulose decomposers for which data of the chemical analyses of the products are given. A comparison of these products is given in Table 1. The poor recovery of the products in the case of *B. cellulose dissolvens* is due in part to the small amount of cellulose digested. On the other hand, the excess recovered in the case of *Cl. thermocellum* is accounted for by the fact that the process of fermentation is a hydrolytic one. Figured on the basis of percentage recovery for each product, Khouvine shows approximately 50 per cent of Viljoen's figures.

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*The Microbiology of Cellulose, Hemicelluloses, Pectins and Gums. Oxford Univ. Press, ndon 61, 1927.

**Centbl. Bakt. (etc.), 2 Abt., 76:40, 1928.

TABLE I. Comparison of the products obtained from the fermentation of cellulose by *Cl. thermocellum* and *B. cellulose dissolvens*.

	Cl. thermocellum	*B. cellulose dissolvens*
Cellulose digested	35.5 gms.	1.01 gms.
Acetic acid found	18.37 gms.	0.275 gms.
Butyric acid found	not given	0.033 gms.
Ethyl alcohol found	5.5 gms.	0.082 gms.
CO_2	11.51 gms.	0.182 gms.
H_2	not estimated	0.008 gms.
Pigment	not estimated	0.013 gms.
Total recovered	35.38 gms.	0.593 gms.
Per cent recovered	112.3	58.76

Lymn and Langwell first reported the results of their experiments with thermophilic cellulose decomposing bacteria in 1923. They stated that the optimum for the organism was 60°C. to 68°C. but on ordinary media they carried out experiments at 20 to 38°C. Under these conditions the growth was similar to, but not as rapid as, that at higher temperatures. On glucose agar they got good development of colonies in 18 hours. Two types of colonies were distinguished. One was flat, round, semi-transparent with a tendency to spread; yellowish in color and moist. The other type developed more rapidly. It was flat, and irregular in outline, opaque white, with crenate edges. These colonies remained clearer in the center than at the edge. Microscopically, the first type was seen to contain few bacilli, but large numbers of "cocci or spores." The second type contained only bacilli. Glucose shake cultures gave gas bubbles below the surface. On nutrient agar the growth was much the same as on dextrose agar but not as good. No growth in gelatin peptone bouillon occurred. Very slow moist growth on potato appeared after 48 hours. Litmus milk was coagulated in five days, acid in 48 hours. Attempts to differentiate between the two types on media failed. They state that the two types are probably two forms of the same organism growing differently because of environment.

To test the cellulose destroying ability of the colonies, such colonies were transferred to a streak culture on peptone agar and after 48 hours the growth was washed off with sterile water and used for inoculation. This was incubated at 60°C. A vigorous fermentation set in which appeared to be quite normal and seemed to follow the course of the usual cellulose fermentation. From this fermentation the following products were obtained: acetic, butyric and lactic acids; alcohol, CO_2, H_2 and CH_4.

Woodman and Stewart (1928) reported their findings as regards the presence of glucose in the course of digestion of cellulose by thermophilic bacteria. They used filter paper which was torn by hand rather than cut with scissors. The fermentation, they say, occurred much sooner if the paper were not cut. Their medium, which was a synthetic one containing calcium carbonate, sodium phosphate, ammonium sulphate, potassium chloride, tap water and paper, was inoculated with 5 gms. of well rotted dung from an old heap. The cultures were incubated at 65°C. After 24 hours, gas appeared, and a "head" was formed

in 36 hours. Fermentation was complete in from 5 to 7 days. Five c.c. transfers were made into fresh flasks of media and by subculturing every seventh day "a pure culture was soon obtained." Growth at 37°C. was unsuccessful.

Their experiments leading to the detection of glucose were as follows: 5 c.c. of culture were added to 100 c.c. of cellulose media in a flask. The flask was incubated at 65°C. for 5 days. The contents were filtered and concentrated at 45°C. in *vacuo*. The residue was tested for sugar with Fehling's solution. Under these conditions no reducing sugar was found. Negative results were also obtained when the culture was tested every 24 hours. Examination of the water in which was suspended a collodion sac culture gave a very weak test for sugar. A flask of inoculated medium was incubated at 65°C. and then 40 c.c. of toluol were added and shaken. The flask was then incubated at 37°C. for 5 days. The filtered solution gave a positive test with Fehling's solution. The osazone was identified as that of glucose. No other osazone could be detected. The authors claimed that the toluol had inhibited the action of the living bacteria and that the enzyme hydrolysing cellulose to glucose continued to function. They stated further that the antiseptic might also function in extracting the enzyme from bacteria. During the life of the organisms any sugar which was formed was immediately changed to lower products, but that after the addition of toluol no such action could have taken place and the sugar accumulated. The fermentation was much less extensive when toluol was present, only about 30 or 40 per cent was fermented. Fermentations carried out at 65°C. and transferred to 37°C. without the addition of toluol gave negative results. Their best results were obtained when the incubator accidently went up to 75°C. for 12 hours.

In common with many investigators they report that once the culture is grown on a medium without cellulose it will never ferment cellulose again. They carried their cultures on plain agar for 13 transfers and in peptone broth for 8 more. After this the cultures would not attack cellulose.

Woodman and Stewart's work cannot be taken too seriously. First, their method of obtaining a pure culture is very crude. In the light of Thaysen and Bunker's as well as Coolhaas's criticisms of Viljoen's work such gross transfers certainly cannot yield a pure culture. Their work with toluol is essentially the same as that done by Pringsheim. The change in temperature to yield an intermediate product has been made with other organisms; the butyric acid bacteria and the butyl alcohol, acetone organism for example*.

Coolhaas (1928) using mud and manure for inocula found that the crude cultures produced CH_4, and CO_2 as gaseous products. The methane fermentation changes over to the hydrogen fermentation after repeated transfers. He regards the former as secondary and as resulting from the decomposition of products of the latter. Attempts were made to get pure cultures from the hydrogen fermentation. Aerobic and anaerobic plates were made using bouillon agar, bouillon agar plus one per cent dextrose, washed agar with inorganic nutrient salts and with one per cent dextrose and also with starch. In some he used NH_4Cl while in others he used asparagin as N source. Colonies of different forms and sizes appeared on the aerobic plates. Few developed on the anaerobic plates. All colonies were inoculated in sterile media with NH_4Cl, asparagin or peptone as N source. No fermentation of paper occurred in any of the cultures. Kellerman's cellulose medium was then used. No growth occurred on anaerobic plates. Many small colonies developed on the aerobic plates after 4 or 5 days

*Thompson W. S. Unpublished M. S. thesis, Univeristy of Wisconsin.

which were surrounded by distinct clear areas. These were transferred to the same medium and cultivated in pure culture. All attempts to ferment cellulose failed. This organism was grown in symbiosis with *Bact. thermobutyricus* but no digestion of cellulose followed.

The bacteria isolated are thin spore bearing rods. The vegetative rods measured 4 to 6 micra, the spore bearing rod, 3.5 to 4 micra by 0.3 micron thick. The bacteria are non-motile and gram positive and do not stain with iodine. Colonies on Kellerman's cellulose agar are round, granulated in the centre, 0.5 to 1 mm. in diameter. The clear space is plainly visible. On bouillon agar plus one per cent sucrose the colonies are somewhat smaller, transparent and glistening. On starch agar the clear zone is larger. Stab cultures show only surface growth. There is no acid produced from sugar, no growth in milk, no nitrate reduction, no gelatin liquifaction, no indol formation nor gas production. The organism is catalase negative. The author suggests the name *B. thermocellulolyticus*.

It seems apparent from the foregoing review that the question of decomposition of cellulose is far from being solved. Much work still needs to be done to show the relationship of the organisms to the process. Then too, if the so-called farm wastes are to be used for industrial purposes, more knowledge of the products of cellulose fermentation is needed. Everything seems to hinge on the isolation of the organisms in pure culture. With the bacteria, this seems to be a difficult problem. No doubt these organisms belong to a different physiological group and new methods will probably have to be developed before much progress is made.

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A COMPARISON OF HALOGENO AND OXYACIDS

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In a recent paper originating in this department and sent to one of the chemical journals for publication the term "fluo acid" was used to designate a flourine containing acid which could be considered as having been formed by substituting two flourine atoms for each oxygen atom in an oxyacid. Criticism of this term on the ground that it was novel and unusual resulted. The paper mentioned being essentially organic in its nature it was impossible to explain the matter sufficiently except as a separate discussion. The purpose of this paper is to make an attempt to establish the term "halogeno acid" as a general name for acids in which the halogens may be considered to replace the oxygen in oxyacids and to establish the terms, fluo, chloro, bromo, and iodo as the specific names of these acids where the halogen involved is flourine, chlorine, bromine, and iodine respectively. As a matter of fact these names have been used in several cases and are accepted terms for those cases, i.e., fluoboric acid, bromostannic acid, fluoplumbic acid, fluosilicic acid, etc.

When various molecular portions of water are added to the anhydrides of the acid forming elements, the several oxyacids are produced.

$$B_2O_3+H_2O\rightarrow 2HBO_2$$
$$B_2O_2+3H_2O\rightarrow 2H_3BO_3$$

In an analogous manner when the halogen acids are added to the halogen compounds corresponding to the anhydrides of the acid forming elements, the halogeno acids are formed.

$$2BF_3+H_2F_2\rightarrow 2HBF_4$$
$$2BF_3+3H_2F_2\rightarrow 2H_3BF_6$$

In Table 1 the anhydrides and oxyacids of several of the elements are given and with these the corresponding halogeno compounds and halogeno acids.

TABLE I

OXYGEN ACIDS			HALOGENO ACIDS		
ACID ANHYDRIDE	MOLECULE of WATER	ACID	ACID HALOGENIDE	MOLECULE of H_2F_2	ACID
Al_2O_3	1	$H_2(Al_2O_4)$	$2AlF_3$	1	$H_2(Al_2F_8)$*
Al_2O_3	2	$H_4(Al_2O_5)$	$2AlF_3$	2	$H_4(Al_2F_{10})$*
Al_2O_3	3	$2H_3(AlO_3)$	$2AlF_3$	3	$2(H_3AlF_6)$*
B_2O_3	1	$2H(BO_2)$	$2BF_3$	1	$2H(BF_4)$
B_2O_3	3	$2H_3(BO_3)$	$2BF_3$	3	$2H_3(BF_6)$
SiO_2	1	$H_2(SiO_3)$	SiF_4	1	$H_2(SiF_6)$
SiO_2	2	$H_4(SiO_4)$	SiF_4	2	$H_4(SiF_8)$†
				Molecule of H_2Cl_2	
Sb_2O_5	1 (Meta-)	$2H(SbO_3)$	$2SbCl_5$	1	$2H(SbCl_6)$
Sb_2O_5	2 (Pyro-)	$H_4(Sb_2O_7)$	$2SbCl_5$	2	$H_4(Sb_2Cl_{14})$‡
Sb_2O_5	3 (Ortho-)	$2H_3(SbO_4)$	$2SbCl_5$	3	$2H_3(SbCl_8)$¶
Bi_2O_3	1	$2H(BiO_2)$	$2BiI_3$	2HI	$2H(BiI_4)$
Bi_2O_3	2	$H_4(Bi_2O_5)$	$2BiBr_3$	4HBr	$H_4(Bi_2BR_{10})$
Bi_2O_3	3	$2H_3(BiO_3)$	$2BiF_3$	6HF	$2H_3(BiF_6)$
SnO_2	1	$H_2(SnO_3)$	$SnBr_4$	2HBr	$H_2(SnBr_6)$

*As NH: Salts.
†As Sn Salt.
‡As Mg Salt.
¶As Cr Salt.

Perhaps the greatest difficulty in the acceptance of this analogy lies in the attempt to write the halogeno acids structurally. When, however, one examines the formula of hydroflouric acid which conductivity measurements have shown to be H_2F_2 this difficulty disappears.

If the formula of H_2F_2 be written structurally it becomes $H-F=F-H$. In substituting two florine atoms for one oxygen atom this grouping has been assumed to hold. Thus where a double bonded oxygen atom is replaced the end valenceies of the $-F=F-$ group are assumed to be the ones involved and the group is written thus $\begin{matrix} \diagup \\ \\ \diagdown \end{matrix}\!\!\begin{matrix} F \\ \cdot\cdot \\ F \end{matrix}$. When a hydroxyl group is substituted it is replaced by the group, $-F=F-H$. The same arrangement of atoms and valenceies has been assumed to be true in the case of the other halogens.

One could continue this table and show the analogy of halogeno acids to oxyacids to hold for practically all of the acid forming elements.

In the table a few of the acids listed are not very stable and from this it might be assumed that the compounds, instead of being written as shown would probably more nearly represent the facts if they were written as a halogen compound of the element and the halogen acid constituting a molecular, that is, one would write $2AlF_3$-H_2F_2 in place of $H_2Al_2F_8$.

When, however, one examines such compounds as $(NH_4)_2(PbCl_6)$ and $(NH_4)_2(SnCl_6)$ the complex salts are more stable than either one of the molecular ingredients, in $2NH_4Cl$-$PbCl_4$ and $2(NH_4)Cl$-$SnCl_4$.

It is also worthy of note that in almost every case the halogeno acids are stronger acids than the corresponding oxyacids. This is to be expected from the periodic arrangement of the elements which places oxygen in group 6 and the halogens in group 7. Thus from the point of atomic structure the halogens are more electropositive than oxygen and would therefore form stronger acids.

While in several isolated cases the above given terminology has been used in chemical literature, so far as we have been able to ascertain the name halogeno acid has not been generally accepted for all acids where the oxygen may be considered to have been replaced by halogen in the ratio of one to two.

Conclusion. 1. We have pointed out the similarity of the halogen substituted oxyacids to the oxyacids themselves.

2. We have proposed the term halogeno acid as a general name for these substituted acids and more specifically the terms fluo, chloro, bromo, and iodo, as the names for these acids when flourine, chlorine, bromine, and iodine respectively are the halogens involved.

STABILITY OF BARIUM SULPHATE AT HIGH TEMPERATURES

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Barium sulphate is almost universally utilized as a precipitate in both qualitative and quantitative analysis of barium salts and of sulphates. In qualitative testing the small solubility of the precipitate is the only important property, since simple recognition is sufficient for the purpose. But in quantitative determinations it becomes necessary to heat the barium sulphate in order to burn filter paper and possible traces of other organic matter, as well as to volatilize moisture and traces of volatile salts.

There has been a widespread belief among analytical chemists that it is necessary to use caution in this heating, on account of danger of decomposition of barium sulphate into barium oxide and sulphur trioxide:

$$BaSO_4 \rightarrow BaO + SO_3.$$

This opinion seems logical, on account of the known decomposition, in a similar manner, of other sulphates, even of the alkaline earth metals. It has received support also from some published reports of investigations, although other researches indicate that only a negligible decomposition occurs, at any temperature that might be attained by use of ordinary laboratory burners. At all events, the caution has been repeated in a good many text books, including those by the senior author of this paper. In the last case this author has felt that as long as there is any doubt about the matter, the only safe course was to use care in the heating, employing a lower temperature for a somewhat longer time.

While it is probably true that many of the published statements and directions are little more than repetitions or expressions of opinion, the following two references to original papers will indicate opposite viewpoints, as a result of experimental work.

Hofman and Warjiekow* plotted decomposition curves for a number of metallic sulphates over a considerable range of temperatures. They showed that barium sulphate is decomposed at ignition temperatures, evolving a mixture of sulphur trioxide and dioxide. This would indicate the necessity for ignition at a temperature only high enough to complete the oxidation of carbon from the filter paper.

Mosttowitsch† investigated the behaviour of pure and impure barium sulphate and found that the pure salt does not appreciably decompose until 1500° is reached, this being only 80° below the melting point. He found that both silica and ferric oxide cause decomposition at lower temperatures, but that even with silica present the precipitate decomposed only at 1000° or above.

From the standpoint of quantitative analysis the question is important only as it concerns decomposition at temperatures obtainable by use of laboratory burners, which may include any of the various modifications of the Bunsen burner, the blast lamp or the Méker burner. In order to obtain some first hand information on the subject, the present investigation was undertaken.

*Bull. Am. Inst. Mining Eng., No. 69 (1907).
†Metallurgie, **6**, 450 (1909).

Barium sulphate was prepared by precipitation from a solution of a high-grade barium chloride, sulphuric acid being used as the precipitant. The usual precautions were taken in precipitation, the barium sulphate being washed free from acid and then dried for five hours at 100°. Sufficient sulphate was prepared for several experiments, avoiding the necessity for burning the paper, since most of the precipitate could be removed without difficulty.

First method of procedure. Samples of about 0.2 gm of sample were heated to dull redness in a platinum crucible until the weight was constant. Small losses occurred during this preliminary heating, due to volatilization of traces of moisture, acid or volatile salts. The crucible was then heated over a Fisher burner (a patented modification of the original Méker burner) for successive periods of two hours. The temperature was probably 900-1000°.

Second method of procedure. This was identical with the first method, except that the barium sulphate sample was first moistened with sulphuric acid and then heated at dull redness to constant weight. This treatment would serve to convert any traces of occluded barium chloride into sulphate, and this to avoid slow volatilization or decomposition of the former during the subsequent heating at higher temperatures.

The results may be summarized as follows:

FIRST METHOD

Exp. No.	Sample weight gm.	Loss at dull redness	Further loss over Fisher burner for additional 2-hour periods		
			1	2	3
1	0.2204	0.0042	0.0003	0.0001	0.0000
2	0.2108	0.0038	0.0004	0.0000	.....
3	0.2094	0.0039	0.0004	0.0001	0.0000

SECOND METHOD

Exp. No.	Sample weight gm.	Loss at dull redness	Further loss over Fisher burner for additional 2-hour periods		
			1	2	3
4	0.2235	0.0055	0.0000	0.0003	0.0000
5	0.2408	0.0048	0.0000	0.0002	0.0000
6	0.2154	0.0045	0.0001	0.0001	0.0000

Conclusions. So far as the results of this work are concerned, it may safely be concluded that it is unnecessary to keep the ignition temperature as low as "dull redness," and that, on the contrary, the small first losses on heating to higher temperatures indicate the desirability of volatilizing traces of other salts by such heating. When precipitation is carried out carefully, occlusion of barium chloride is not a serious source of error.

POND WATER COMPOSITION AND MOSQUITOES

R. H. Carr, Purdue University

The writer frequently has had occasion to spend some weeks on a farm near Wooster, Ohio where there is a fish pond supplied with water from a fountain. It has been a matter of considerable pleasure and no little curiosity to find that there are no mosquitoes near this pond although they are plentiful about 1,000 feet away in any direction one might go. About 75 feet from this pond there is a creek which runs considerable water the year around and there are many mosquitoes both up and down this stream especially in the more marshy spots along its banks. In trying to find a possible reason for their absence about the vicinity of the pond the most promising answer seemed to center in the difference between the composition of the water from the fountain and that from the creek. The latter is a rather soft water drawn from surface drainage and springs along the hillsides whereas the fountain water is a very hard mineral water which cattle and horses prefer to that of the creek.

The table which follows gives a partial analysis of this fountain water in parts per million. The analysis was made by the Water Softening and Purification Works Laboratory of Columbus, Ohio.

Alkalinity	347
Non-carbonate hardness	63
Total hardness	410
Magnesium	38
Anhydrous sulphuric acid SO_4	150
Chlorine as chlorides Cl	11
Calcium	102
Total Solids	592

It will be noted from the table that the water is quite alkaline containing a considerable quantity of magnesium, sodium, calcium, bicarbonate, also magnesium and sodium sulphate with a total solids content of 592 P. P. M.

The water runs from a 2″ iron pipe and flows into a cement trough. This soon becomes covered with a precipitate probably largely composed of iron hydrate and carbonate. At one place on the outside of the trough where the cement wall is somewhat porus water has seeped through slowly and a white deposit of magnesium sulphate has been formed. The water flows from the trough to a pond which covers about half an acre. The water with its extensive mineral content seems a culture solution for many kinds of water plants such as *Bidens connota, Juncus effusus, Cyperus gragii*, etc., and especially a very green alga which grows luxurioulsly in the pond but not in the creek during July and August. The presence of algae seems to be associated usually with an abundance of mosquitoes hence their absence in this instance often causes comment. It is possible that the basic condition of the water may be unfavorable to the growth of mosquito larvae as MacGregor* found that tree-hole mosquitoes bred

*MacGregor, M. E. The influence of the hydrogen-ion concentration in the development of mosquito larvae. Parasitology, **13**: 1921.

in water at pH 4.4, but when transferred to water with a pH of 8.2-8.4 they succumbed or remained stunted.

Rudolph and Lackey† carried on similar studies and noted when pH of water changed rapidly the larvae were killed in 24 hours but a gradual change did not greatly affect the death rate. It is possible that the change in pH is partly responsible for the death of larvae in this pond as the calcium and sodium bicarbonate present in the water are rapidly decomposed by water plants during the hours the sun is shining producing a more basic water due to the formation of calcium and sodium carbonate. Osterhout and Haas have suggested that this change in pH, caused by decomposition of $NaHCO_3$ to Na_2CO_3 while the sun shines, might be used to measure the rate of photosynthesis under controlled conditions. The death of the larvae in the pond may be due to the alkaline water or change of pH from this cause but it still does not account for the absence of mosquitoes close to the pond since there must be many other breeding places where the supply in the vicinity is produced, hence some other reason for their absence must be found.

The water from this fountain comes from one hundred feet beneath the ground and is very cold, 48 degrees F, when it reaches the surface. Upon standing under atmospheric conditions gasses are formed as the water warms and the pressure is released. This is evidenced from the deposit formed in the cement trough as well as when the water is placed in a bottle the gas released amounts to approximately 80 cubic centimeters per gallon. No detailed analysis of this gas has been made as yet but tests have shown it to contain some sulphur dioxide, and carbon dioxide.

The writer does not claim much intimate acquaintance with the mosquito and the life history of the different families of this king of pests, but it is hoped that this brief study of the conditions surrounding one of nature's mosquito protected spots may throw some light on how protection may be had in regions where the little bug is halting the march of civilization.

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†Rudolphs, W. and Lackey, J. B. The compostion of water and mosquito breeding. Amer. Jour. of Hygiene, **9**:1-60. 1929

‡Osterhour, W. J., Hass, A. R. C. A simple method of measuring photosynthes Sci. **47**:1217-1918.

CONCERNING CERTAIN PYRIDINE HOMOLOGS

Jacob W. H. Aldred with Robert E. Lyons, Indiana University

Ladenburg has synthesized certain of the simpler alkaloids from pyridine homologs, for example coniine[1] from 2-methylpyridine. Moreover, pyridine or its homologs are found among the decomposition products of many of the important alkaloids, hence it is believed that other alkaloids can be built up from these simple bases if the proper methods are employed. For instance, nortropane is an intermediate between pyridine and tropine. It can be converted into 2-ethylpyridine, or into tropine, by proper treatment. Attempts[2] have been made to convert 2-ethylpyridine into nortropane. The authors consider 2:6-di. methylpyridine a better starting material than the ethyl isomer for this synthesis. Linking two methyl-groups, after halogenation, to produce the desired seven-membered ring should be easier than linking the ethyl-group at the proper place on the pyridine nucleus.

Residues from the commerical rectification of pyridine were used as a source of 2:6-dimethylpyridine. The method for separation and purification outlined by Heap, Jones and Speakman[3] was followed. Fractional distillation of the dry bases brings about partial separation of the homologs. The fraction boiling at 137°±2°C. is composed largely of the 2:6-dimethylpyridine and a smaller quantity of 3-methylpyridine. The approximate proportions of these two bases are reversed in the fraction boiling at 143°±2°C. The 3-methylpyridine was removed as the double zinc chloride salt. The non-crystallizable mother liquid was then converted into the double mercuric chloride salt for separation of the 2:6-dimethylpyridine. The proportions of reagents recommended by Heap, Jones and Speakman for the production of these double salts failed to give us well formed salts. In order to overcome this difficulty, the proportions of the reagents were varied; this caused a change in the composition of the resulting salts, however, their physical constants showed that pure products had been obtained.

Bromination of the methyl-group of the pure base, 3-methylpyridine, was carried out. Monobrom-3-picolyl hydrobromide dibromide was obtained by the use of an excess of bromine upon a solution of the base in carbon tetrachloride, maintained at the boiling temperature and exposed to sunlight.

The great difficulty of purification of the bases and of the brominated product lead to the attempt at chlorination of the fractions obtained by distillation without further purifying them. We sought thereby to eleminate one of the lengthy separation procedures in preparing pure halogenated pyridyl compounds. The chlorinating agent was nascent chlorine produced by the action of hydrogen chloride on potassium chlorate, both in the aqueous and in the anhydrous condition. A crystalline substance, having the formula $C_5H_3Cl_3$ was produced in about constant amounts with either chlorination mixture. The dry chlorination mixture yielded resinous trichloropyridines, one of which was isolated in the hydrated form.

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[1]Ladenburg, Ber.**14**,2409 (1881); **17**,1676 (1884); **18**,1587 (1885); **19**,439,2578 (1886); **22**,1403,2583 (1889);**26**,854 (1893); **27**,3062 (1894); **28**,163,1991 (1895).

[2]Ladenburg and Adams, Ber. **24**,1671 (1890).

[3]Heap, Jones and Speakman, J. Am. C. S. **43**,1876,1936 (1921).

Sell and Dootson[4] have studied the action of phosphorous pentachloride upon pyridine and of dry chlorine upon fused pyridine hyrochloride. From these reaction mixtures, they isolated the highly chlorinated derivatives of pyridine, the pentachloride, all of the tetrachlorides and three of the trichlorides. A tar remained, which they presumed contained lower chlorinated derivatives. We have not been able to separate from the resinous mixture any substance containing more than three chlorine atoms per molecule. The trichloropyridine isolated from this reaction mixture appears to have very weak basic properties, or none at all, for it forms neither double salts nor an hydrochloride.

Apparatus. The mixture of the dry bases was fractionated by means of a ten-section Young and Thomas still head. One portion of the bases was fractionated through the Young and Thomas still head connected in series with two Dufton type columns as used by Wilke and Shaw[5]. The apparatus was put together with cork stoppers. The pyridine disintegrated the stoppers, even when wrapped with tin-foil, rather rapidly. The three column still gave good fractionation but the leakage was great. Therefore, most of the bases were distilled four times through the single still head rather than once through the triple column head. The receivers were protected from the moisture of the air by means of a calcium chloride tube.

The pure bases were dried at the boiling temperature over solid caustic soda in a flask sealed to a condenser tube, the upper end of which carried a calcium chloride tube.

A three neck, 500 cc. pyrex flask constituted the reaction vessel for the chlorination experiments with dry materials. This flask was equipped with an inlet tube of wide bore for bringing in the hydrogen chloride, a stirrer bearing a mercury seal and a reflux condenser.

Experimental. *3-Methylpyridine Zinc Chloride Hydrochloride.* A cooled mixture of 1 mole of zinc chloride, 1 mole of hydrochloric acid and 2 moles of water was added slowly, with cooling, to 2 moles (methylpyridine) of each of the pyridine fractions boiling at 137°±2°C. and 143°±2°C. respectively. The resulting mixture was cooled with ice until the crystallization was complete. The viscous mass was filtered with suction, whereby most of the non-crystalline zinc chloride double salts were removed. Recrystallization of the residue four times from alcohol gave a white crystalline substance having a constant melting point of 175°. Analysis: 0.5008g.Sbst.: 27.75 cc.N/10HCl—0.4555g.Sbst.: 0.0829g. Zn. (electrolytic), 0.5125g.Sbst.: 42.24 cc. N/10 $AgNO_3$, $(C_6H_7N)_2$. $ZnCl_2$.HCl.Calc. Base 51.88, Zn 18.13, Cl 29.71. Found Base 51.37, Zn18.1, Cl 29.3.

The base was liberated with excess sodium hydroxide, extracted with ether, the extract dried and the ether removed. The base so obtained distilled completely between 143.6°C. and 143.8°C. (all of mercury column immersed in vapor), barometer 747 mm. Analysis: 0.3005g.Sbst.: 0.8521g.CO_2, 0.2121g.H_2O C_6H_7N. Calc. C 77.4, H 7.5. Found C 77.6, H 7.9.

The picrate melted at 149°C., the auric chloride salt at 179°C., the platinic chloride salt at 224°C., the mercuric chloride salt at 145°C., the carboxylic acid at 230°C.

2,6-Dimethylpyridine Mercuric Chloride Tetrahydrate. The viscous filtrate obtained from the preparation of the 3-methylpyridine zinc chloride was made

[4]Sell and Dootson, J. C. S. Trans. **73**,432 (1898); **75**,979 (1899); **87**,799 (1905).

alkaline and steam distilled. This distillate was acidified with hydrochloric acid and concentrated. Hot aqueous mercuric chloride solution was added to the concentrated distillate until precipitation was complete. Recrystallization of the product from fifth normal hydrochloric acid gave blade-like crystals. To free the dimethylpyridine salt from the accompaning methylpyridine salt, the hot concentrated acid solution was cooled slowly to near room temperature. When needles began to appear, the blade-like crystals were quickly filtered free of the mother liquid. Repeating this operation a few times produced a salt of constant composition melting at 178°C. Analysis: 0.5531g.Sbst.: 7.5 cc. N/10HCl. —0.5047g.Sbst.: 0.0.2961g, HgS.—0.5071g.Sbst.: 0.5047g. AgCl. $(CH_3)_2$. $C_5H_3N.HCl.2HgCl_2.4H_2O$. Calc. Base 14.2, Hg 52.8, Cl 23.5. Found Base 14.7, Hg 50.6, Cl 24.6.

The base obtained from this salt boiled at 138°±0.5°C. at 745 mm. Analysis: 0.3012g.Sbst.: 0.8651g. CO_2, 0.2217g. H_2O. C_7H_9N. Calc. C 78.5, H 8.4. Found C 78.4, H 8.2.

The platinic chloride salt melted at 209°C.

Monobrom-3-picolyl Hydrobromide Dibromide. 10g. of 3-methylpyridine in 100 cc. of carbon tetrachloride and a small crystal of iodine were placed in a 250 cc. transparent silica flash fitted with a reflux condenser. The apparatus was set up outside of the window to permit conducting the bromination in direct sunlight. To the boiling solution, 27 g. of bromine dissolved in 40 g. of carbon tetrachloride were added dropwise over a period of about two hours, and the mixture refluxed for an hour after the addition of the bromine was completed. The brominated product separated as a heavy brown oil. The free bromine was extracted with several portions of carbon tetrachloride. Large brown crystals were obtained from the oil when dissolved in a mixture of equal volumes of alcohol and ethyl acetate. After decolorization and recrystallization, pale yellow thick prisms were obtained, melting at 200°C. The picrate melted at 207°C. The crystals lost their pale yellow color when exposed to the air for a few days, becoming covered with a white film. Heating to 110° causes slow volatilization. Analysis: 0.1250g.Sbst.: 0.0797g. CO_2, 0.0237g. H_2O—0.1054g.Sbst.: 5.04 cc. N/10 $Na_2S_2O_3$—0.1995g.Sbst.: 0.3592g.AgBr.$BrCH_2.C_5H_5N.HBr.Br_2$.
Calc. C 17.35, H 1.93, Br (perbromide) 38.7, Br(total) 77.4. Found C 17.35, H 2.12, Br(perbromide) 38.3, Br(total) 76.7.

Chlorination with Aqueous Hydrogen Chloride and Potassium Chlorate. One mole of pyridine (fraction distilling below 130°) was mixed with 4.5 moles of concentrated hydrochloric acid. To this was added one third mole of a hot saturated solution of potassium chlorate. Chlorine was evolved, the solution turned yellow and a precipitate formed. The amount of material separating bore a constant ratio to the quantity of base used in the reaction. This substance, when filtered off and recrystallized from alcohol, separated as slender needles, melting at 217°. Melting points had to be taken quickly before the material sublimed to the cold portion of the tube. The analytical data approximated the formula $C_8H_5Cl_3$ $1.5H_2O$. 0.1527g.Sbst.: 0.2340g. CO_2, 0.0385g. H_2O—0.1846g.Sbst.: 0.3281g. AgCl. $C_8H_5Cl_3.1.5H_2O$. Calc. C 40.6, H 3.4, Cl 45.2. Found C 41.8, H 2.8, Cl 44.4.

This compound gives neither a precipitate with alcoholic silver nitrate, nor a blue color with starch-potassium iodide solution, nor a double salt with platinic chloride. These tests show that it is not basic. This substance has been

formed either by chlorination of a hydrocarbon or by the condensation of non-nitrogenous remnants from the cleavage of the pyridine nucleus.

After removal of the precipitate, the acid mixture was distilled under reduced pressure. Chlorine, water and hydrochloric acid were removed before any of the pyridine derivatives started to volatilize. The separated potassium chloride was filtered off when it caused excessive bumping. The hydrochlorides of the pyridine bases distilled between 130° and 138° at 10 mm. Fractions were taken at each degree. When sodium hydroxide solution was added to these solid distillates, a brown solution resulted. Dehydrated nagnesium sulfate, although slower in removing the water, was used to dry the ether extract of the base rather than the usual solid sodium hydroxide, since the caustic soon became covered with a brown resin. The brown gum or resin which remains after distilling off the ether and the pyridine from the dried ethereal extract, chars, with evolution of hydrogen choride, when strongly heated, but does not volatilize. Since no method for preparing a crystalline product from this brown resin could be found, it was not analysed.

The results show that only small quantities of chlorinated substances are obtained by the action of aqueous hydrogen chloride-potassium chlorate mixture upon pyridine.

Chlorination with Dry Hydrogen Chloride and Potassium Chlorate. Difficulties are to be anticipated in the use of this chlorinating mixture, since the chlorine dioxide, produced by the action of hydrogen chloride upon potassium chlorate, is a powerful oxidizing agent, which reacts explosively with many substances. Although pyridine is very resistant to oxidation, its hydrochloride will char if the temperature of the reaction mixture reaches 140°C.

To execute this method of chlorination, the base and the chlorate were placed in a flask equipped with a condenser, a stirrer and an inlet tube for hydrogen chloride. Keeping the reaction mixture below 75°C., slow introduction of hydrogen chloride and efficient stirring are essential to the smooth procedure of the reaction. The potassium chlorate does not enter the reaction until most of the base has been changed to the hydrochloride. Solid hydrochlorides collecting on the sides of the flash permit local overheating, which starts a violent reaction with the evolution of hydrogen chloride and the formation of a tar. This type of decomposition usually results when the temperature of the reaction mixture is kept above 75°C. after the potassium chlorate begins to react. The fact that pyridine hydrochloride has a low melting point and, when fused, dissolves the hydrochlorides of the higher homologs to some extent, permitted the use of fractions boiling below 130°C., while higher boiling fractions gave a reaction mass which could not be kept broken up. The end of the reaction was marked by the evolution of free chlorine, which was evidently due to the action of the water formed in the reaction inhibiting the union of chlorine and pyridine while not affecting the action of hydrogen chloride on the chlorate. If only 0.05 mole of water was added to the reaction mixture, chlorine was freely evolved after the hydrochloride was formed and the amount of the chlorinated product was greatly decreased.

One mole of pyridine and one third mole of potassium chlorate were treated with 2.2 moles (10% excess) of dry hydrogen chloride. Such a ratio of reagents will produce the hydrochloride and slightly more chlorine than will enter into reaction with the base. The resulting product was a pasty mass. The potassium

chloride could be removed quantitatively by filtering and washing the residue with absolute alcohol.

Pouring the resulting filtrate into a large amount of water produces a yellow flocculent precipitate. The aqueous solution (to be designated as portion A), obtained by removal of the material insoluble in water (portion B) contains the hydrochloride of the base and a chlorinated derivative similar to, if not the same as, the chlorinated derivative which separated as a brown tar when the base was distilled in the experiments with the aqueous chlorinating mixture.

Portion B was resinous, dissolving readily in alcohol and acetone, slightly in ether and ethyl acetate, scarcely at all in water, benzol and carbon disulfide. A solution of the resin B in alcohol or in acetone deposited crystals in about the same amount, having the same melting point and composition as those obtained from the aqueous chlorinating mixture. No other crystalline substance was separated. Steam or direct distillation caused decomposition without separating any volatile substance. Reducing the pressure did not change these results.

A mixture of trichloropyridines was obtained by the purification or decompositon produced by repeatedly dissolving the resin B in alcohol and pouring the solution into water. The substance during this treatment became lighter in color and lost its power to liberate iodine from potassium iodide. When dried over phosphorous pentoxide under vacuum, the material had a light tan color, subsequent drying at 110°C. caused only a slight darkening, while if the moist precipitate was placed in an oven at 110°C. considerable blackening occurred and some hydrochloric acid was liberated. The material dried at 110°C. discolors at 170°C. and melts with frothing at 177°C. A small amount of a platinic chloride salt separates as flattened pale yellow diamond shaped crystals, melting at 258°C., whenever the alcoholic solution is evaporated almost to dryness.

Dissolving the resin in hot concentrated nitric acid liberated quantities of nitrogen peroxide and gave a yellow solution, which, when poured into water, yielded a yellow precipitate. When freed from nitric acid by reprecipitating the alcoholic solution with water and dried, a clear brittle resin was obtained melting at 90° C. with much frothing. Drying at 110°C. to determine water of hydration was impossible, since hydrogen chloride was freely evolved. Analysis: 0.2985g.Sbst.: 0.3104g. CO_2, 0.0507g. H_2O—0.2971g.Sbst.: 0.5598g. AgCl.—0.4198g.Sbst.: 23.5 ccm. N (27°/745 mm.) $C_5H_2NCl_3.1.5\ H_2O$. Calc. C 28.6, H 2.4, N 6.7, Cl 51.0. Found C 28.4, H 1.9, N 6.0, Cl 51.0.

This trichloropyridine does not form salts with platinic chloride or with mercuric chloride; it gives no precipitate with silver nitrate. The arrangement of the chlorine atoms is such, therefore, that the basic properties of the nitrogen atom are neutralized. Treatment with alcoholic ammonia in a sealed tube at 180°C. caused a change in the composition of the resin but crystallizable products could not be isolated from the resulting reaction mixture. The investigation is to be contined.

I. ORGANIC COMPOUNDS OF SELENIUM

W. E. Bradt and M. Van Valkenburgh, University of Cincinnati

Introduction. Because selenium and some of its compounds are now available in considerable amounts at reasonable prices, the investigation of the preparation and properties of organic selenium compounds is quite feasible. In order to further this work, the senior author plans a series of papers which, when completed, will present: (a) a classification of the known organic selenium compounds based on the analogous oxygen and sulphur types, (b) a complete list of all known organic selenium compounds, (c) a resume of the chemistry and methods of preparation developed for each class of compounds, and (d) a complete bibliography for each known organic selenium compound.

The physiological action of some of the more common inorganic selenium compounds is well known. Many organic selenium compounds are reported to exhibit valuable therapeutic and tinctorial properties. However, the investigation of these properties has been so incomplete that organic compounds of selenium are still only of scientific interest. It is hoped that a systematic presentation of the chemistry of organic selenium compounds, with a statement of the extent of the synthetic work accomplished to date, will create interest in developing the possibilities of service to mankind (dyes, medicinals etc.), which probably exist in this field. Investigation in this direction lends itself particularly to the worker who has available only limited equipment. The reactions can usually be conducted in apparatus which is always available or which may be easily prepared.

Aliphatic Selenols

In this group will be discussed compounds, represented by the following formulas, in which "R" is a methyl group, the hydrogen atoms of which may or may not be replaced by other groups.

1. $R-CH_2-SeH$ 2. $R_2=CH-SeH$ 3. $R_3\equiv C-SeH$
4. $R-Se-SeH$ 5. $R_3\equiv Se-SeH$

Aliphatic selenols or seleno mercaptans have been prepared by four methods: (a) the interaction (1) of an alkali acid selenide and an alkyl iodide or bromide, (b) the interaction (2, 3, 4) of an alkali acid selenide or H_2Se and a calcium or potassium alkyl sulphate, (c) aluminum selenide (5) or hydrogen selenide reacting on an aliphatic alcohol at 250-300°C., and (d) the decomposition (6, 7) of a selenocyanate. Air must be excluded when making these preparations

Primary Selenols. Only three primary selenols have been isolated. They are *ethyl selenol*, *n-propyl selenol* and *n-butyl selenol*. They are heavy, colorless liquids with an extremely intense disgusting odor. They are insoluble in water, precipitate with salts of the heavy metals, those with lead and thallium being most characteristic, and form soluble seleno mercaptides (I) with the alkali metals. In air they are quickly converted to diselenides, (I) RSeSeR, and with the Grignard reagent, they yield (1) RSeMgI and hydrocarbons (II) quantitatively.

I. $2RSeH+\frac{1}{2}O_2 \rightarrow R-Se-Se-R+H_2O$.

II. $RSeH+CH_3MgI \rightarrow R-SeMgI+CH4$. Alkyl halides with sodium ethylate convert primary selenomercaptans into selenides, (III) $R-Se-R$.

III. $R-SeH+NaOC_2H_5+R-Cl \rightarrow R-Se-R+C_2H_5OH+NaCl$. Halogen derivatives, such as $Br-(CH_2)n-Br$, under the same conditions give diselenides such as $C_2H_5Se(CH_2)nSeC_2H_5$; except ethylene bromide, which forms ethylene and diethydiselenide (IV).

IV. $2C_2H_5SeNa+Br-C_2H_4-Br \rightarrow C_2H_5-Se_2-C_2H_5+C_2H_4+2NaBr$.

Secondary Selenols. The only secondary selenol which has been prepared is isopropyl selenol, $CH_3-CHSeH-CH_3$. It was prepared (60% yield) in 1926 (5) by action of Al_2Se_3 at 260-270°C. on isopropyl alcohol (V).

V. $3(CH_3)_2=CHOH+Al_2Se_3 \rightarrow 3(CH_3)_2=CHSeH+Al_2O_3$. Isopropylselenol boils at 70°-75°C.

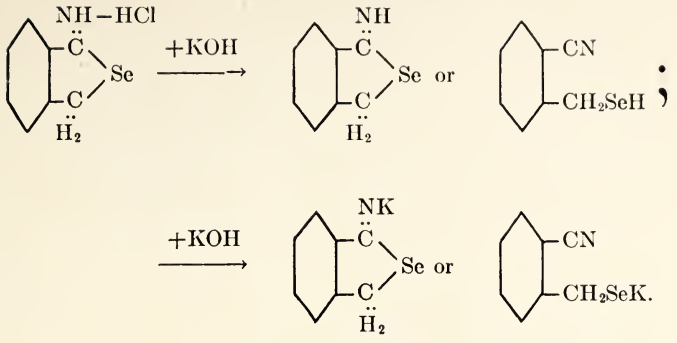
Aromatic Primary Selenols. The aromatic alcohol, o-nitrobenzyselenol, or *o-nitrobenzylselen mercaptan*, $o\text{-}NO_2-C_6H_4CH_2SeH$, is prepared (6) by dissolving *o*-nitrobenzylselenocyanate (Prepared (VI) from *o*-nitrobenzylchloride and potassium selenocyanate) in aqueous alkali (VII). A red brown solution forms with the evolution of the odor of cyanogen.

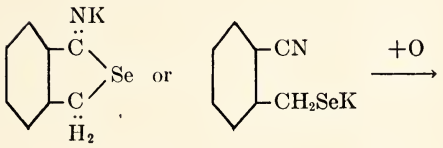
VI. $o\text{-}NO_2-C_6H_4CH_2Cl+KSeCN \rightarrow o\text{-}NO_2-C_6H_4CH_2SeCN+KCl$.

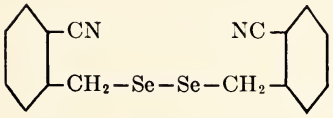
VII. $2o\text{-}NO_2-C_6H_4CH_2SeCN+H_2O+KOH \rightarrow 2o\text{-}NO_2-C_6H_4CH_2SeH+2CN+O-$. The reaction is probably as indicated by equation (VII). If so, further investigation may demonstrate the formation of other products which would make the accuracy of the equation appear more probable. Since the evolution of oxygen would obviously oxidize the selenol to a diselenide ($R-Se-Se-R$) (I), the presence of the selenol as a final product is indication of the loss of oxygen with the formation of other oxidation products.

o-Cyanobenzylselenol, o-cyanobenzyl selenomercaptan, $o\text{-}CN-C_6H_4CH_2SeH$, or *selenophthalimidine*, (See Table I.) is prepared (7) by the action of concentrated H_2SO_4 on *o*-cyanobenzylselenocyanate (VIII).

VIII. $o\text{-}CN-C_6H_4CH_2SeCN+H_2SO_4 \rightarrow o\text{-}CN-C_6H_4CH_2SeH+CO_2+NH_3$ The resulting product is an oil which crystallizes gradually. It exhibits both acid and basic properties and is soluble in solution containing an excess of either acid or base. Salts with HBr, HCl, H_2SO_4, H_2PtCl_6 and picric acid were formed which had the following formulas ($C_8H_7NSe=R$): $R-HCl$; $R-HBr$; $R=I_2$; $R-C_6H_3(NO_2)_3OH$; $R=H_2PtCl_6$ and $R_2=H_2SO_4$. The addition of a base to a solution of these salts of selenophthalimidine or *o*-nitrobenzylselenol at first forms a precipitate (IX), which redissolves on the addition of an excess of the base. This basic solution is very easily oxidized by the air (?) to the corresponding diselenide (X).

IX 

X 



Selenonium Selenols. *Tri-ethylselenonium selenol, tri-ethylselenitine hydroselenide* or *tri-ethylselenonium hydroselenide*, $(C_2H_5)_3{=}Se{-}SeH$, was prepared (8) according to the reactions represented by equations (XI) and (XII).

XI. $C_2H_5Br + C_2H_5{-}Se{-}Se{-}C_2H_5 \rightarrow Br.(C_2H_5)_2{\equiv}Se{-}Se{-}C_2H_5$.

XII. $MgBrC_2H_5 + Br.(C_2H_5)_2{\equiv}Se{-}Se{-}C_2H_5 + HOH \rightarrow C_2H_5OH + MgBr_2 + (C_2H_5)_3{\equiv}Se{-}SeH$. It is a dense yellow oil with a disagreeable odor, which reacts with alcoholic silver nitrate to form triethylselenonium nitrate and silver selenide (XIII).

XIII. $(C_2H_5)_3{\equiv}Se{-}SeH + 2AgNO_3 \rightarrow (C_2H_5)_3{\equiv}Se{-}NO_3 + Ag_2Se + HNO_3$. This reaction demonstrates the properties of the selenol group which is attached to a tetravalent selenium atom. In this respect triethylselenonium selenol is not a true selenol.

Table I lists all of the aliphatic selenols, which have been prepared prior to 1929, with their formulas, boiling points and references to their mention in the literature. It will be noticed that three unsubstituted primary, two substituted primary, only one secondary, and no tertiary selenols have been prepared. Also, no selenide selenol ($R{-}Se{-}SeH$) where the selenol group is attached to a bivalent selenium atom, has been prepared and only one selenonium selenol ($R_3{=}Se{-}SeH$) in which the selenol group is attached to a tetravalent selenium is listed. No unsaturated aliphatic selenols have been prepared.

TABLE I. ALIPHATIC SELENOLS

Name	*Formula*	*B. P. C.*	*Ref. Nos.*
Ethyl selenol	C_2H_5SeH	53.5	1, 2, 3, 4, 5, 9, 10
n-Propyl selenol	C_3H_7SeH	84.	1.
Iso-propyl selenol	$(CH_3)_2=CHSeH$	70.-75.	5.
n-Butyl selenol	C_4H_9SeH	114.	1.
o-Nitrobenzyl selenol	o-NO_2-$C_6H_4CH_2SeH$	....	6.
o-Cyanobenzyl selenol	o-CN-$C_6H_4CH_2SeH$	....	7.
Tri-ethyl selenonium-hydroselenide	$(C_2H_5)_3\equiv Se$-SeH	....	8.

SELENOALDEHYDES

Selenoaldehydes may be represented by the formula, R−CHSe, in which "R" is hydrogen, an aromatic, or aliphatic organic radical. Unfortunately, no molecular weights have been determined for each of the four members of this group, which have been prepared prior to 1929. Accordingly it is very probable that some of the selenoaldehydes are polymerized. The selenium analogues of formaldehyde, acetaldehyde, isovaleraldehyde, and benzaldehyde have been prepared (11) by the action of hydrogen selenide on the corresponding aldehydes (XIV).

XIV. $R-CHO+H_2S \rightarrow R-CHSe+H_2O$.

Aliphatic Selenoaldehydes. Selenoformaldehyde, (HCHSe)n, which is obtained by passing hydrogen selenide into 36 per cent aqueous formaldehyde mixed with three times its volume of concentrated hydrochloric acid, separates from alcohol as a polymer in columnar crystals melting at about 215°C. It is very sparingly soluble in most organic media and becomes light green on exposure to sunlight.

When hydrogen selenide is passed into a solution of acetaldehyde in three volumes of alcohol, which has been saturated with hydrogen chloride; and the resulting semi-solid mass crystallized from alcohol, *selenoacetaldehyde*, CH_3CHSe, is obtained in slender transparent needles (m.p. = 139°C.). Selenoacetaldehyde separates from acetone in crystals which melt at 123-124°C. If chloroform is used as a solvent, the resulting product melts at 117°C. Selenoacetaldehyde thus apparently exists in several modifications.

The passage of a stream of hydrogen selenide through a solution of isovaleraldehyde in water yields (12) an oily compound, selenoisovalderaldehyde, $(CH_3)_2=CH-CH_2-CHSe$, which on standing in the cold, forms a crystalline mass. This is volatile with steam. A vapor density determination has not been conducted because it is reduced by metallic mercury. Likewisc it has not been successfully crystallized. In a solution of ether, alcohol, or methyl alcohol, it slowly decomposed with the formation of a metallic mirror of selenium. Only through sublimation at ordinary temperature was purification obtained. A beautiful white crystalline crust melting at 56.5°C. was thus formed. It has a terrible odor and those working with it, frequently suffer from palpitation of the heart and difficulty in breathing.

Aromatic Selenoaldehydes. In 1875, Granville Cole (13) prepared *selenobenzaldehyde*, C_6H_5CHSe, by heating an alcoholic solution of potassium selenide with benzylidine chloride, (XV).

XV. $C_6H_5CHCl_2+K_2Se \rightarrow C_6H_5CHSe+2KCl$. It crystallized in yellow needles, which had a very unpleasant odor and dissolved easily in alcohol and ether, but not in water. It resembled its analogue, thiobenzaldehyde, in that its ethereal solution was not affected by dry ammonia, or by a heated mixture of hydrocyanic and hydrochloric acids. Cole found its m.p. to be 70°C., but Vanino and Schinner in 1915 prepared (11) crystallized "alpha"-selenobenzaldehyde in clusters of yellow transparent columns, melting at 83-84°C. They, apparently in ignorance of Cole's work, prepared it, by passing hydrogen selenide for 3-4 hours into an alcoholic solution of benzaldehyde, (XVI).

XVI. $C_6H_5CHO+H_2Se \rightarrow C_6H_5CHSe+H_2O$. When the alcohol was previously saturated with hydrogen chloride, a mixture of "beta" and "gamma" selenobenzaldehyde was obtained, which was resolved into its constitutents by taking advantage of their different solubilities in benzene. "Beta"-selenobenzaldehyde, the more sparingly soluble form, crystallized from benzene in lustrous, golden needles m.p. about 205°C., of the composition $3C_6H_5CHSe.C_6H_6$. The benzene mother liquors yielded on evaporation "gamma"-selenobenzaldehyde, which crystallized in slender pale yellow needles, (m.p. = 166°C.). When distilled with copper powder "beta"-selenobenzaldehyde was converted into stilbene.

SELENOKETONES

A few compounds which are listed in the literature (14) under names indicating a selenoketone structure, are misnamed and are in reality selenides of oxygen ketones. The name selenoketone should indicate the replacement of the oxygen of the ketonic carbonyl group by selenium to give a compound of the type (R = organic carbon radical) $R_2=C=Se$. Each (15) member of this group prepared prior to 1929 has been isolated in a polymerized condition in which the selenoketone contains two of the original ketone structures.

Aliphatic Seleno Ketones. *Diselenoacetone*, $(CH_3CSeCH_3)_2$, was prepared (15) by conducting hydrogen selenide through a cooled mixture of equal volumes of acetone and concentrated hydrochloric acid until no further reaction was noticeable (XVII).

XVII. $2CH_3COCH_3+2H_2Se \rightarrow (CH_3CSeCH_3)_2+H_2O$. From the turbid mixture, a heavy red oil separated with a yield of fifty per cent by volume. After washing with water and distilling with steam at a temperature of 45-60°C., diselenoacetone, a clear red oil of unpleasant garlic odor was isolated. It is not miscible with water, only slightly soluble in glacial acetic acid, and is miscible in benzol and chloroform without decomposition. The solution on standing in 95 per cent alcohol precipitates red selenium. When benzene or chloroform solutions of any of the known seleno ketones are subjected to the action of chlorine, decomposition occurs with separation of selenium tetrachloride.

Diselenomethylethyl ketone, $(CH_3-CSe-C_2H_5)_2$, is prepared (15) from methyl-ethyl-ketone in a similar manner (XVI). The product is a dark red oil, which when washed, steam distilled under atmospheric pressure, and dried in a vacuum, is a clear, red, mobile oil, resembling diselenoacetone in its appearance and odor. It is volatile with steam without decomposition at ordinary pressures.

Aromatic Seleno Ketones. As yet only one aromatic ketone, *diselenoacetophenone*, $(CH_3CSeC_6H_5)_2$, has been prepared. This was prepared (15)

from acetophenone according to the general procedure described above (XVI). A red oil not volatile in steam was obtained. The remaining unchanged acetophenone and other volatile contaminations were removed by treatment of the crude product with steam. The non-volatile part was then dried and identified as diselenoacetophenone. It is a red, viscous oil, which possesses an odor similar to that of diselenoacetone.

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II*. ORGANIC COMPOUNDS OF SELENIUM

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Organic Selenium Acids

Organic selenium acids may have any of five formulas. These are (R = any organic carbon radical):

1. Selenol acids, R−C=O−SeH.
2. Seleno acids, R−C=Se.OH.
3. Selenol-seleno acids or diseleno acids, R−C=Se.SeH.
4. Seleninic acids, R−Se=O.OH.
5. Selenonic acids, R−SeO_2.OH.

Only one selenol acid and only derivatives of the seleno and selenol-seleno acids have been prepared prior to 1929. However, numerous examples of the seleninic and selenonic acids are known. The seleninic and selenonic acids which are analogous respectively to sulfinic and sulfonic acids, may be considered as derivatives of the inorganic selenious and selenic acids.

Selenol Acids. The only known selenol acid, *selenol benzoic acid*, C_6H_5COSeH, was called "*alpha*-selenobenzoic acid" by Mingoia. He prepared it (1) by the interaction at 100° C. of magnesyl selenhydrate and an ether solution of benzoyl chloride (I).

I. $BrMgSeH + C_6H_5COCl \rightarrow C_6H_5COSeH + MgBrCl$. After acidification of the product with H_2SO_4, extraction with ether, and crystallization from methyl alcohol, lustrous rose colored crystals were obtained which melted at 133°C. Selenol benzoic acid is soluble in aqueous alkali hydroxides, carbonates and NH_4OH with formation of salts. Ammonium selenol benzoate, $C_6H_5COSeNH_4$ is easily decomposed by oxygen and by water. The acid, however, is more stable than the sulfur analogue.

Seleno Acids. Although none of the acids of this group have been isolated, five of the acid amides have been prepared. These will be discussed as acid amides of selenium acids.

Selenol-Seleno Acids. The only known representative of this group is the ethyl ester of *selenol-seleno carbonic acid* (2), (3). The potassium salt, which has been isolated, is better known as an analogue of potassium zanthogenate, and is therefore called *potassium seleno xanthogenate*. It has been prepared by the action of carbon diselenide on potassium alcoholate (II).

II. $C_2H_5OK + CSe_2 \rightarrow C_2H_5OCSeSeK$. The potassium selenoxanthogenate separates as yellow needles which are easily soluble in alcohol and in water. It is very easily decomposed. No free acid of this group has been isolated.

Seleninic Acids. Seleninic acids contain tetravalent selenium and accordingly may be considered as analogues of either sulfinic or carboxylic acids. They

*This paper is the second in a series which will ultimately present a classification of the prepared selenium organic compounds and a resume of the chemistry and literature pertaining to them.

are, moreover, correctly considered as derivatives of selenious acid, H_2SeO_3. Seleninic acids were among the organic selenium compounds first discovered. Because of this fact, there is some confusion in the literature (2, 4, 5) regarding the formula for one or two compounds placed in this group. The authors have endeavored to reinterpret this early data in the light of information which is now available regarding the general properties and methods of preparation of these compounds.

A total of twenty seleninic acids has been reported in the literature. Five are derivatives of aliphatic compounds, while in the remaining fifteen, the selenium atom is attached to a cyclic carbon atom. The methods of preparation include the oxidation of diselenides, $R-Se-Se-R$, by nitric acid, alkaline permanganate or alkaline hydrogen peroxide; the oxidation of selenols, $R-SeH$, by nitric acid or alkaline permangante; the action of nitric acid on selenocyanates, $R-SeCN$; the action of hydrogen peroxide on aryl "selenoglycollic" acids, $R-Se-CH_2COOH$; the action of nitric acid or H_2O_2 on the diethylselenomercaptoles, $R_2=C=(Se-C_2H_5)_2$, of a few ketones; and finally by the reduction of the corresponding selenonic acid, $R-SeO_3H$, with concentrated hydrochloric acid.

A complete list of the seleninic acids prepared prior to 1929, with melting points, formula, and references to their mention in the literature is given in Table I.

In 1856 Wohler and Dean (4) reported the formation (III) of a crystalline compound, melting at 122°C., by the interaction of dimethyldiselenide and nitric acid.

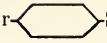
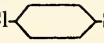
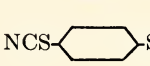
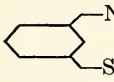
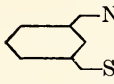
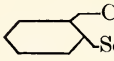
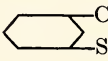
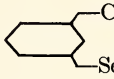
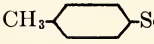
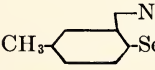
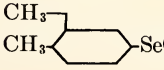
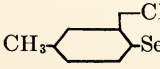
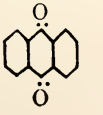
III. $CH_3-Se-Se-CH_3+4HNO_3 \rightarrow 2CH_3-SeOOH.HNO_3+2NO$. This substance, of which the nitric acid solution formed a white precipitate upon the addition of HCl, probably (6) was the nitric acid compound of *methyl seleninic acid*, $CH_3-SeOOH.HNO_3$. Their analysis of the hydrochloride derivative, from which the formula, $(CH_3-SeO(OH)Cl)_2$, was derived was found by Rathke (2) to indicate the hydrochloride of the acid, $CH_3SeOOH.HCl$. Since similar compounds result on the addition of HCl to solutions of most seleninic acids, this is assumed to be the product obtained. Methyl seleninic acid forms compounds with hydrochloric acid, CH_3SeOOH-HCl, and with nitric acid, CH_3SeOOH-HNO_3. The latter is soluble in water and in alcohol, and crystallizes in colorless prisms melting at 122°C. The ammonium, barium, and silver salts have been prepared.

Methane diseleninic acid. In 1874 Proskauer (5) reported that the action of nitric acid on methane diselenocyanate formed the diselenonic acid. If this is true, the reaction is quite unusual. Other examples of the oxidation of the selenocyanate group by nitric acid have uniformly given seleninic acid. Also it is known (25) that oxidation of organic selenium by fuming nitric acid in the Carious treatment stops with the formation of selenious acid. No hexavalent selenium is formed. Because of these facts, the writers assume that the product formed was methane diseleninic acid (IV).

IV. $CH_2(SeCN)_2+2HNO_3 \rightarrow CH_2(SeOOH)_2+2NO+(CN)_2$. In 1852 Joy (8) treated diethyldiselenide with strong nitric acid but was not able to isolate the product which was certainly the nitric acid compound of *ethyl seleninic acid*, $C_2H_5SeOOH.HNO_3$, m.p. = 80°C. (V).

V. $C_2H_5-Se-Se-C_2H_5+4HNO_3 \rightarrow 2C_2H_5SeOOH$-$HNO_3+2NO$. The addition of HCl to a solution of this product made possible the isolation of a crystalline product, reported by Joy to be $2C_2H_5-SeO-OH-Cl$, and considered by Rathke (2) who repeated this work in 1869 to be the hydrochloride of ethyl

TABLE I. SELENINIC ACIDS

Names	*Formula*	*M.P.°C*	*Ref. Nos.*
Methyl-	$CH_3-SeOOH$	.....	6, 2, 4.
Methane-di-	$HOOSe-CH_2-SeOOH$	.....	5.
Ethyl-	$C_2H_5-SeOOH$	.....	6, 2, 7, 8.
Ethane-di-	$HOOSe-CH_2-CH_2-SeOOH$	.....	5.
Benzyl-	$C_6H_5CH_2-SeOOH$	122-3	9, 10, 11.
Phenyl-	$C_6H_5-SeOOH$	124-5	12, 13, 14, 15.
p-Bromophenyl-		187 (?)	16, 17.
p-Chlorophenyl-		178 (?)	17, 18.
p-Thiocyanophenyl-		154	17.
m-Nitrophenyl-		156	12, 19.
m-Acetaminophenyl-		209	12, 19.
o-Carboxyphenyl-		228	20, 21.
o-Toluene-		126-7	22, 23.
m-Toluene-		119-20	22.
p-Toluene-		171	22, 23.
2-Nitro-*p*-toluene-		151	17.
o-Xylene-4-		125	22.
m-Xylene-4-		146-7	22.
2-Anthraquinone-		.....	24.

seleninic acid, C_2H_5SeOOH-HCl. That this was correct, was established by Shaw and Reid (6) who prepared the same substance (m.p. = 100−107°C. with decomposition) by the oxidation of ethylselenol with nitric acid (VI); and subsequent addition of HCl; as well as by the oxidation (by nitric acid, or by a 3 per cent solution of H_2O_2) of the diethylseleno-mercaptoles of acetone (VII), methylethyl ketone and diethyl ketone.

VI. $3C_2H_5SeH+7HNO_3 \rightarrow 3C_2H_5SeOOH-HNO_3+4NO+2HOH.$

VII. $(CH_3)_2C=(SeC_2H_5)_2+4H_2O_2 \rightarrow 2C_2H_5SeOOH+CH_3COCH_3+3HOH.$

Shaw and Reid found that the action of HBr on the nitrate of ethyl seleninic acid formed ethylselenonium tribromide, $C_2H_5SeBr_3$, which they state (6) is a "new type of compound." However, the literature mentions more than seventy selenonium compounds, several of which are very similar to ethylselenonium tribromide. The formation of this tribromide and the corresponding tri-iodide led Shaw and Reid to propose a selenonium formula for the hydrochloride of the acid, $C_2H_5-\underset{\underset{Cl}{|}}{\overset{\overset{OH}{|}}{Se}}-OH$. This is further supported by Karve (7), who reported data indicating that ethyl seleninic acid is a "pseudo acid" even in aqueous solution.

Ethane diseleninic acid. In 1874 Proskauer (5) treated $(NCSe-CH_2-)_2$ with nitric acid and reported the formation of ethane *alpha-beta* diselenonic acid. He prepared the lead, barium and silver salts. In view of the usual action (25) of nitric acid on selenium the product was probably a diseleninic acid (VIII). No analysis was reported.

VIII. $C_2H_4(SeCN)_2+2HNO_3 \rightarrow CH_2)SeOOH)_2+(CN)_2+2NO.$ Jackson (10, 11) and Lesser and Weiss (9) formed benzyl seleninic acid by treating dibenzyldiselenide with fuming nitric acid (IX).

IX. $C_6H_5CH_2-Se-Se-CH_2C_6H_5+2HNO_3 \rightarrow 2C_6H_5CH_2-SeOOH+2NO.$

It crystallizes from the acid liquid on cooling in stellate groups of needles which may be purified by recrystallization from hot water or alcohol. It melts at 122-123°C., (Jackson reported 85°C.,) has a strong acid reaction, and expells carbonic acid from carbonates. The ammonium salt, formed by neutralizing the acid with ammonia, is a white substance which crystallizes with difficulty and is very freely soluble in water. The silver salt, $C_6H_5CH_2SeOOAg$, is obtained as a curdy precipitate on adding silver nitrate to the ammonium salt. Benzyl seleninic acid is converted by PCl_5 into dibenzyl selenonium dichloride, $(C_7H_7)_2SeCl_2$, (m.p. = 134-135°C.). It is insoluble in cold water, alcohol, and ether, but easily soluble in nitric acid. The sodium and barium salts formed by neutralizing the acid with the respective carbonates, are freely soluble in water. The lead salt, precipitated by lead nitrate from the ammonium salt, is a white crystalline powder, nearly insoluble in water.

In 1896 Krafft & Lyons (13) dissolved one part by weight of diphenyl diselenide in forty parts of concentrated nitric acid and heated. On cooling the well-crystallized nitrate of *phenylseleninic acid* separated (m.p. = 112°C.) The nitrate exhibits properties of both an acid and a base, indicating a selenonium structure, $C_6H_5-Se\begin{matrix}\diagup OH \\ - OH \\ \diagdown NO_3\end{matrix}$ which may be in equilibrium with the form, C_6H_5SeOOH-HNO_3. In 1906 Stoecker and Krafft (15) prepared the free acid as

white crystals melting at 122-124°C, by treating the silver salt with HCl. They reported the formation of a hydrate, $C_6H_5SeOOH.H_2O$, which decomposed on heating. However, Doughty, (14) who prepared phenyl seleninic acid by the reduction of phenyl selenonic acid with concentrated HCl, (X), and Pymen (12) in 1919, showed that phenyl seleninic acid crystalized as the anhydrous acid, C_6H_5SeOOH, and that heating formed the acid anhydride (XI).

X. $C_6H_5SeOOH+HCl \rightarrow C_6H_5SeOOH+H_2O+Cl_2$.

XI. $2C_6H_5SeOOH \rightarrow C_6H_5SeO-O-OSeC_6H_5+H_2O$. The Ag, Ba, Cu, and Na salts have been described. Phenyl seleninic acid is soluble in water and is reduced by zinc and HCl to phenyl selenol (XII).

XII. $C_6H_5SeOOH+2H_2 \rightarrow C_6H_5SeH+2H_2O$. The nitrate and copper salt detonate on heating.

p-Bromophenyl seleninic acid was first prepared (16) in 1925 by treatment of *p*-bromophenyl selenoglycollic acid, $p-Br-C_6H_5-Se-CH_2COOH$, with H_2O_2 (XIII).

XIII. $p\text{-}Br-C_6H_4-Se-CH_2COOH+H_2O_2 \rightarrow p\text{-}Br-C_6H_4SeOOH+.....$ The product was at first considered to be a selenoxide but in 1927 Porritt (22) established the fact that it was a seleninic acid. The same acid was prepared in 1928 (17) by treatment of $p\text{-}Br-C_6H_4-SeCN$ with HNO_3 (XIV).

XIV. $2p\text{-}Br-C_6H_4-SeCN+2HNO_3 \rightarrow 2p\text{-}Br-C_6H_4SeOOH+2NO+(CN)_2$. *p*-Bromophenylseleninic acid is soluble in $CHCl_3$, alcohol, hot water, slightly soluble in cold water and forms crystals from water melting at 113°C. An insoluble copper salt and soluble salts of ammonia and the alkali metals have been described.

A well cooled aqueous solution of *p*-chlorobenzenediazonium chloride, sodium acetate, and alcoholic potassium selenocyanate gives *p*-chlorophenylselenocyanate (XV). With aqueous alkali this substance forms the corresponding selenol which is oxidized to the diselenide by hydrogen peroxide. Oxidation of either of these compounds with alkaline permaganate gives (18) the sodium salt of *p-chlorophenylseleninic* or *p-chlorophenylselenious acid*. This acid (colorless needles from hot water, m.p. = 178°C.) is produced by boiling the sodium salt with hydrochloric acid.

XV. $2p\text{-}Cl-C_6H_4-N=N-Cl \rightarrow 2p\text{-}Cl-C_6H_4-SeCN \rightarrow 2p-Cl-C_6H_4-SeH \rightarrow (p\text{-}Cl-C_6H_4-Se-_2) \rightarrow 2p\text{-}Cl-C_6H_4-SeOONa \rightarrow 2p\text{-}Cl-C_6H_4-SeOOH$. The nitration (17) at 3°C. of *p*-chlorophenyl selenocyanate yields mainly the diselenide with some *p*-chlorophenyl seleninic acid (XVI).

XVI. $4p\text{-}Cl-C_6H_4-SeCN+2HNO_3 \rightarrow (p\text{-}Cl-C_6H_4-Se-)_2+2p\text{-}Cl-C_6H_4SeOOH+NO+(CN)_2$. It is an amphoteric substance, giving rise to metallic *p*-chlorophenylselenites and to salts of the mineral acids, such as the nitrate and hydrochloride.

When *p*-thiocyanophenylselenocyanate, is nitrated at 3°C., *p-thiocyanophenylseleninic acid* is formed (17) by a reaction similar to (XVII).

Although aniline sulfate and arsenate readily yield sulfanilic acid and arsanilic acid, respectively, at an elevated temperatrue, no similar selenium compound could be obtained by Pyman. However, by the nitration of phenylseleninic acid, he (12, 19) prepared a 20% yield of *m-nitrophenylseleninic acid* (XVII).

XVII. $C_6H_5-SeOOH+HNO_3 \rightarrow m\text{-}NO_2-C_6H_4-SeOOH+H_2O$. This acid forms yellow needles (m.p. = 156-7°C.). It is reduced successively (XVIII)

to *m*-nitrophenyl diselenide, yellow spears, m.p. =83°C., then to *m*-aminophenyldiselenide, and is oxidized by $KMnO_4$ to the selenonic acid.

XVIII. $m\text{-}NO_2-C_6H_4-SeOOH \rightarrow (m\text{-}NO_2-C_6H_4-Se-)_2 \rightarrow m\text{-}NH_2-C_6H_4-Se-Se-C_6H_4-NH_2\text{-}m$. The dihydrochloride of the amine forms yellow grains melting at 291-2°C. *m*-Nitrophenyl seleninic acid is fairly soluble in hot and sparingly soluble in cold water. It crystallizes from the latter in prismatic needles.

Di-*m*-aminophenyldiselenide gives on acetylation di-*m*-acetylaminophenyldiselenide, from which *m-acetylaminophenylseleninic acid* is obtained (12, 19) by oxidation with nitric acid. *m*-Acetylaminophenylseleninic acid melts with decomposition at 209°C. and is sparingly soluble in hot water. The nitrate (m.p. = 146°C.), the ammonium salt and sodium salt have been isolated.

An aqueous solution of *o*-carboxyphenyl selenonic acid is transformed (21) (XIX) by hydrochloric acid into *o-carboxyphenyl seleninic acid*, or *o-seleninbenzoic acid*, *o*-$HOOSe-C_6H_4COOH$. (See below.) This acid is also obtained (20, 21) by the oxidation of diphenyldiselenide-di-*o*-carboxylic acid by nitric acid or by alkaline H_2O_2 (XX).

XIX. $o\text{-}HOOC-C_6H_2-SeO_3H+HCl \rightarrow o\text{-}HOOC-C_6H_4-SeOOH+H_2O+Cl_2$.

XX. $2o\text{-}HOOC-C_6H_4-Se-Se-C_6H_4-COOH\text{-}o + 2H_2O + 3O_2 \rightarrow 4o\text{-}HOOC-C_6H_4-SeOOH$. When heated at 130-140°C. until constant in weight this acid is transformed into the anhydride without change in melting point. It crystallizes from water in long glistening needles which melt at 228-29°C.

On reduction (23) of a concentrated mixture of *o* and *p*-tolueneselenonic acids with hydrogen chloride, *p-tolueneseleninic acid*, $CH_3C_6H_4SeOOH.H_2O$, was precipitated in long silky white needles melting at 160°C.; while the mother-liquor yielded *o-tolueneseleninic acid* with ½ H_2O in nodules of short, white needles with a m.p. of 99-101°C. Analysis indicated the presence of water of crystallization but its presence was not definitely established. Porritt also prepared (22) each of these acids and *m-tolueneseleninic acid* (m.p. = 119-120°C.) by oxidation of the corresponding toluene selenoglycollic acids (XXI) with cold H_2O_2.

XXI. $CH_3-C_6H_4-Se-CH_2COOH+H_2O \rightarrow CH_3-C_6H_4-SeOOH+\ldots$. He obtained each in anhydrous form as colorless needles. The *o*-toluene seleninic acid prepared by him melted at 126-127°C. while the *para* compound melted at 171°C. *o*-Toluene seleninic acid is soluble in alcohol, $CHCl_3$, H_2O and is slightly soluble in ether. The action of nitric acid (17) on p-toluene selenocyanate caused both oxidation of the selenium and nitration, forming *2-nitro-p-toluene seleninic acid* which melts at 151°C. (XXII).

XXII. $p\text{-}CH_3-C_6H_4-SeCN+HNO_3 \rightarrow p\text{-}CH_3-(NO_2)-C_6H_4-SeOOH+NO+H_2O$. Other seleninic acids mentioned in the literature are *o-xylene-4-seleninic acid* and *m-xylene-4-seleninic acid*, (See Table II). They were prepared (22) by oxidation of the corresponding selenoglycollic acids with H_2O_2. (See equation XXI). The former melts with decomposition at 125°C. and the latter at 146-147°C. *2-Anthraquinone seleninic* acid results (24) from the action of concentrated HNO_3 on 2-anthraquinone selenol. It separates as colorless crystals.

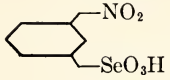
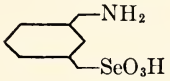
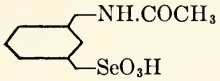
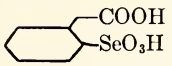
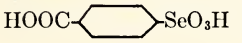
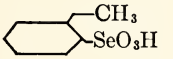
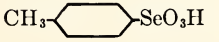
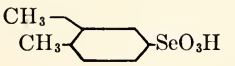
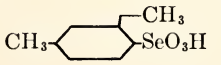
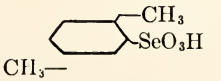
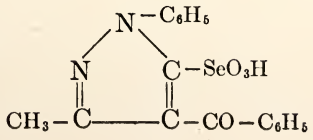
Selenonic Acids. Selenonic acids, $R-SeO_3H$ may be prepared by two general methods: (a) the action of concentrated selenic acid on a hydrocarbon (XXIII), and (b) the oxidation of tetravalent organic selenium (XXIV).

XXIII. $R-H+HO-SeO_3H \rightarrow R-SeO_3H+H_2O$.

XXIV. $2R-Se-Se-R+5O_2+2H_2O \rightarrow 4R-SeO_3H$. Variations of the second method include the oxidation of diselenides by aqueous chlorine, alkaline permanganate and 30% H_2O_2 in acetic acid; and oxidation of the corresponding seleninic acid by permanganate.

Selenonic acids are reduced by concentrated HCl to the corresponding seleninic acid and to selenols by H_2S, SO_2, or Zn and HCl. Table II includes a

TABLE II. SELENONIC ACIDS

Name	*Formula*	*M.P.°C.*	*Ref. Nos.*
Methyl-	CH_3SeO_3H	not isolated	4.
Phenyl-	$C_6H_5SeO_3H$	142	14,15,26
m-Nitrophenyl-		.....	12.
m-Aminophenyl-		229	12, 19
m-Acetaminophenyl-		.....	12, 19.
o-Carboxyphenyl-		.....	19, 27
p-Carboxyphenyl-		not identified	23.
o-Toluene		.....	23.
p-Toluene		.....	23.
o-Xylene-4- (?)-		108-110	28, 29.
m-Xylene-4-(?)-		130-130.5	28.
p-Xylene-2-(?)-		95-96	28, 29.
4-Benzoyl-1-phenyl-3-methyl-pyrazole-5-		152	30.

list of the selenonic acids found in the literature with formulas, melting points and references. It will be seen that no aliphatic selenonic acid has been isolated.

In 1856, Woehler and Dean (4) precipitated the hydrochloride of methyl seleninic acid by adding HCl to a dilute nitric acid solution of methyl seleninic acid. They observed however, that addition of HCl to a concentrated nitric acid solution failed to give a precipitate of $CH_3SeOOH.HCl$. It is quite possible that the selenium was oxidized with formation of a soluble *methyl selenonic acid.*

Methane diselenonic acid and *ethane diselenonic acid* were reported by Proskauer (5) in 1874. However, since his methods of preparation indicate the probable formation of seleninic acids, these compounds have been considered under that heading.

The *"ethyl selenonic acid"* which Fabian (31) reported in 1861 was in reality an ethyl ester of selenic acid $C_2H_5O-SeO_3H$, and was erroneously named by him.

In 1889, Chabrie (26) obtained an acid by the interaction of H_2SeO_4 and benzene. This acid, which formed a soluble barium salt was probably *phenyl selenonic acid,* $C_6H_5SeO_3H$. Doughty (14) later prepared *phenylselenonic acid,* by this method and isolated it as colorless needles. Stoecker and Krafft (15) prepared (XXV) it by the oxidation of diphenyl diselenide with moist chlorine at 50°C.

XXV. $C_6H_5SeSeC_6H_5+5Cl_2+6H_2O \rightarrow 2C_2H_5SeO_3H+10HCl$. It was isolated in the form of its white crystalline silver salt. This detonated feebly when heated. Phenyl-selenonic acid deposits red selenium when exposed to light, and may be reduced to the selenol by HCl and zinc, H_2S or SO_2. The Cu, Ag, Ba, and Cd salts have been prepared. The free acid crystallizes from the water in anhydrous crystals which melt at 142°C., and decompose above 180°C., with the formation of CO_2 and H_2O. It is soluble in water, alcohol and insoluble in ether and benzene.

Pyman (12, 19) prepared *m-nitrophenyl selenonic acid,* $m\text{-}NO_2-C_6H_5.SeO_3H$, by oxidation of the corresponding seleninic acid with alkaline $KMnO_4$. He crystallized the acid from water in colorless plates containing two molecules of water which were lost at 100°C. The anhydrous acid melted at 142°C. He also prepared (12, 19) salts of *m-acetaminophenyl selenonic acid,* $m\text{-}CH_3CO-C_6H_4-SeO_3H$, by the same method. Boiling the barium salt with aqueous H_2SO_4 caused hydrolysis and *m-aminophenyl selenonic acid* separated from the cold filtered solution in colorless needles which melted at 229°C.

o-Carboxyphenyl selenonic acid, or *"o-selenonbenzoic acid,"* $o\text{-}HOOC-C_6H_4-SeO_3H$ is prepared (21, 27) by the oxidation of di-*o*-carboxyphenyldiselenide with alkaline potassium permanganate solution (XXVI).

XXVI. $o\text{-}HOOC-C_6H_4-Se-Se-C_6H_4-COOH\text{-}o+H_2O+5(O) \rightarrow 2o\text{-}HOOC-C_6H_4-SeO_3H$. It is a very strong acid, the salts of which are not decomposed by dilute nitric acid. It has not been obtained in the crystalline state but yields a barium salt which separates from water in colorless, anhydrous needles (9). It is reduced by concentrated HCl to the corresponding seleninic acid.

In 1912, Doughty and Elder (23) treated *p*-toluene seleninic acid with potassium permanganate and obtained a dibasic acid which was possibly *p*-carboxyphenyl seleninic acid, but which more probably was *p-carboxyphenyl selenonic acid.* The potassium salt melted at 264°C. At the same time (23) the formation of a mixture of *o-toluene selenonic acid* and *p-toluene selenonic acid* was obtained by the action of concentrated selenic acid on toluene. Neither was isolated, but both were reduced by HCl to the corresponding seleninic acids and identified.

The action of H_2SeO_4 on *o*-, *m*- and *p*-xylene yielded (28, 29) respectively products partially identified as *o-xylene-4-selenonic acid*, *m-xylene-4-selenonic acid* and *p*-xylene-2-selenonic acid. In each case, although the location of the selenonic acid group has not been definitely established, it is probably in the position indicated. Each was prepared in good yield by adding 96% H_2SeO_4 dropwise to the xylene in the presence of an equal volume of acetic anhydride. Salts of NH_3, K, Na, Ba, Mg, Zn, Ni, Co, Cu and Ag, have been described for each acid. *o*-Xylene-4-selenonic acid melts at 108-110°C., *m*-xylene-4-selenonic acid at 130-130.5°C., and *p*-xylene-2-selenonic acid at 95-96°C.

2-Anthraquinone selenonic acid, is found in the literature (24) due to an error. The original article, refers to the seleninic acid, which has been previously described.

The only selenonic acid of a heterocyclic compound mentioned (30) in the literature is *4-benzoyl-1-phenyl-3-methyl pyrazole-5-selenonic acid*. This acid (See Table II), which melts at 152°C., is obtained by the oxidation of the corresponding diselenide in acetic acid by thirty per cent H_2O_2 according to (XXIV). It may be crystallized as colorless needles from benzene and ligroin, is soluble in NH_4OH, aqueous alkalis, ether and $CHCl_3$, and sparingly soluble in water. Treatment with halogens yields tetra-halides of the type $R-Se_2X_4-R$.

Acid Anhydrides

Carbon diselenide, which may be considered as the anhydride of selenol-seleno carbonic acid, $HO-CSeSeH$, has been prepared (2, 3) in poor yield by the treatment of carbon tetrachloride with either CdSe or P_2Se_5 (XL).

XXVII. $7CCl_4+3CdSe \rightarrow CSe_2+SeCl_4+3CdCl_2+3C_2Cl_6$. Not more than three ccm. have been prepared at one time. It possesses a very disagreeable odor which when diluted, resembles that of carbon di-sulfide. Its reaction with sodium alcoholate has been previously described.

The anhydride of phenyl seleninic acid, has been prepared (28) (XXVIII) by heating the acid at 130°C.

XXVIII. $2C_6H_5-SeOOH \rightarrow (C_6H_5SeO)=O+H_2O$. It sublimes at about 130°C., melts at 164°C., and decomposes at 200°C. Stoecker and Krafft, (15) reported the acid as a hydrate, $C_6H_5SeOOH.\ H_2O$, melting at 122°C., which when heated at 130°C., gave the acid. Doughty concluded that the compound melting at 122°C. was the acid and that Stoecker and Krafft, had prepared the acid anhydride. The anhydride of *o-carboxyphenyl seleninic acid* or *o-seleninbenzoic acid* has been obtained (21) free by heating the acid at 130-140°C., until constant in weight. It is transformed into the anhydride, $(o\text{-}HOOC-C_6H_4-SeO)_2=O$, without change in the melting point, which remains 228-229°C. The anhydride is stable in dry air.

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TWO FORT WAYNE WELLS IN THE SILURIAN, AND THEIR BEARING ON THE NIAGARAN OF THE MICHIGAN BASIN

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About a year ago, Professor Logan, State Geologist of Indiana, submitted to the writer complete sets of cuttings from two deep wells in the southwestern part of Fort Wayne. The samples were taken every ten feet, from surface to bottom of the wells. Accurate data as to surface elevation and location were furnished. The two wells are 2,400 feet apart. Well No. 1 is near the corner of Ardmore avenue and South street, and well No. 2 is near the corner of Taylor street and Henrietta avenue. They were drilled by the Fort Wayne Water Company. The wells are 16 inches in diameter, and the cuttings often show fragments of fair size, so that accurate determinations of the character of the rock can easily be made. These wells are, therefore, of unusual value for geologic correlations. They are 640 and 630 feet deep, and reach the bottom of the Liston Creek limestone.

Because of their importance the logs are given in great detail, with description of each ten-foot sample. Following the detailed description of the well sections, is a discussion of other well sections in the Michigan Basin region, and of the general problem of Niagaran correlations in the region. The writer has visited in the field all of the important sections of the Niagaran around the Michigan Basin, with the exception of Manitoulin Island. For that he depends on the sections given by M. Y. Williams (1919), and Walter A. Verwiebe (1927). The correlations suggested are tentative; but they are based on a wide range of field studies, and will have to be seriously considered in all future studies of the region.

Well No. 1. Surface elevation, 755.2 feet A. T.

1. 0- 10 ft. Yellow silty boulder clay.
2. 10- 20 ft. Gray silty clay with pebbles and sand.
3. 20- 30 ft. Same as 2.
4. 30- 40 ft. Gravel.
5. 40- 50 ft. Gray silty boulder clay with small pebbles.
6. 50- 60 ft. Gravel with pieces of silt.
7. 60- 70 ft. Gravel.
8. 70- 80 ft. Gravel.
9. 80- 90 ft. Two fragments of limestone. Large one brownish gray, granular, porous, with crystals of calcite. Small one light brown, fine grained, with conchoidal fracture.
10. 90-100 ft. Fragments of glacial pebbles mixed with fragments of light brown finely granular crystalline dolomite and chert.
11. 100-110 ft. Fine fragments and dust of fine grained dolomite, with some chert, and material derived from the glacial drift.

GREENFIELD DOLOMITE.

12. 110-120 ft. Almost white, pure, fine grained dolomite. No chert. Top of the

HUNTINGTON DOLOMITE.

13. 120-130 ft. Browner to gray finely granular crystalline, porous dolomite.
14. 130-140 ft. Light brown finely saccharoidal, crystalline dolomite. A few white and a few dark fragments.
15. 140-150 ft. Light gray to white or bluish, somewhat mottled, finely crystalline dolomite.
16. 150-160 ft. Very light, almost white, saccharoidal dolomite. Looks like typical Huntington.
17. 160-170 ft. Almost white, saccharoidal dolomite.
18. 170-180 ft. Same as No. 17. A few dark fragments.
19. 180-190 ft. Same as 18.
20. 190-200 ft. Same.
21. 200-210 ft. Coarser grained, white, saccharoidal dolomite. One particle of chert. One olive green piece.
22. 210-220 ft. Quite saccharoidal. More fragments of light brown and dark gray.
23. 220-230 ft. White porous saccharoidal dolomite. A few dark pieces.
24. 230-240 ft. Soft white, crumby, porous dolomite. Under the lense looks almost like sandstone.
25. 240-250 ft. Same as 24.
26. 250-260 ft. Same. Perhaps slightly darker.
27. 260-270 ft. About the same. Not quite so coarse.
28. 270-280 ft. Slightly brown. Does not effervesce quite so much as preceding samples. Probably somewhat more dolomitic. One quite large fragment quite porous.
29. 280-290 ft. Light grayish brown, finer grained, scarcely at all saccharoidal. Some white *chert*. Top of NEW CORYDON member.
30. 290-300 ft. About the same color. Slightly more granular. Very little chert.
31. 300-310 ft. Browner, but with some white pieces. Weak effervescence. *Chert* more common than in 30.
32. 310-320 ft. Gray to brown, medium fine grained, finely granular. *Chert* rare. A few splinters.
33. 320-330 ft. Darker grayish brown, finely granular. Weak effervescence. Some *chert*.
34. 330-340 ft. Browner, dense, some *chert*. Effervesces more freely.
35. 340-350 ft. Medium gray, dense, some white *chert*, and one piece of dark chert. Slight effervescence.
36. 350-360 ft. Brown, dense, very little effervescence. Specks of white *chert*.
37. 360-370 ft. Brown, with white *chert*. Weak effervescence.
38. 370-380 ft. Same as 37. Base of NEW CORYDON member.
39. 380-390 ft. A few fragments like 38, but many large flakes of bluish gray, *shaly*-looking rock.
40. 390-400 ft. Bluish gray, decidedly *shaly*. Slight effervescence. No chert and no brown dolomite.
41. 400-410 ft. Very light *almost white*, fine grained. Strong effervescence. Few gray particles.
42. 410-420 ft. White limestone.

43. 420-430 ft. Same. A little white chert. Fair effervescence.
44. 430-440 ft. White limestone. Effervesces rather strongly. Many large flakes of dark gray shale.
45. 440-450 ft. Dense, fine grained, very light gray dolomite. Weak effervescence. A few blue flakes.
46. 450-460 ft. Dense, fine grained flaky limestone. Light gray. Fair effervescence.
47. 460-470 ft. Almost white, saccharoidal dolomite.
48. 470-480 ft. Decidedly saccharoidal, white, granular dolomite.
49. 480-490 ft. Same as 48.
50. 490-500 ft. White, coarse, crystalline dolomite.
51. 500-510 ft. White saccharoidal dolomite, mottled with streaks and spots of blue.
52. 510-520 ft. Same as 51.
53. 520-530 ft. Same as 51.
54. 530-540 ft. Same as 51. Very crystalline.
55. 540-550 ft. Coarse, white, saccharoidal dolomite. Mottled. Very porous Slight effervescence.
56. 550-560 ft. Light gray, crystalline, coarse, mottled dolomite.
57. 560-570 ft. Dense, fine grained, light gray, in very small chips with sharp edges. Fair effervescence. Top of LISTON CREEK LIMESTONE.
58. 570-580 ft. Very *cherty*, light gray, dense, flaky limestone. Large, sharp-edged flakes. Effervesces strongly.
59. 580-590 ft. Dense, medium gray, flaky limestone. Good effervescence.
60. 590-600 ft. Slightly darker gray, dense, flaky, sharp-edged, limestone fragments. Some *chert*. Slightly porous. Has the look of typical Liston Creek limestone.
61. 600-610 ft. Finely pulverized, slightly argillaceous, gray, flaky, mottled limestone.
62. 610-620 ft. Mottled, medium gray, flaky limestone. Sharp-edged fragments. Good effervescence.
63. 620-630 ft. Medium gray, dense, sharp-edged fragments. Somewhat mottled. A little *chert*.
64. 630-640 ft. Light gray, dense, almost lithographic limestone. Flaky. Like typical Liston Creek limestone. Fragment of *Orthothetes*? About the base of the LISTON CREEK LIMESTONE.

Well No. 2. Surface elevation, 754.52 feet A. T.

1. 0- 5 ft. Yellow silty clay.
2. 5- 10 ft. Gray pebbly clay.
3. 10- 15 ft. Same as 2.
4. 15- 20 ft. Very pebbly clay.
5. 20- 25 ft. Hard gray silty clay.
6. 25- 30 ft. Gray pebbly clay.
7. 30- 35 ft. Hard gray silty clay.
8. 35- 40 ft. Same as 7.
9. 40- 50 ft. Gravel.
10. 50- 55 ft. Silty clay and pebbles.
11. 55- 63 ft. Gravel and sand.
12. 63- 70 ft. Fine angular sand.

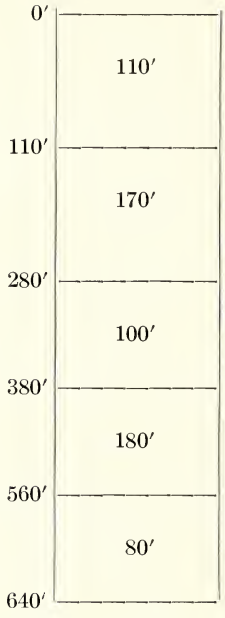
13. 70- 80 ft. Light brown, fine grained, granular, drusy dolomite. Some particles light blue, lithographic. GREENFIELD DOLOMITE.
14. 80- 90 ft. Half and half brown and light blue, fine grained dolomite. The blue chips indicate a finely laminated rock.
15. 90-100 ft. Some fragments dark gray to brown, and a very few fine grained light gray. A few large fragments of very light gray, saccharoidal dolomite.
16. 100-110 ft. Mostly gray granular dolomite. A few fragments of fine grained, buff, splintery dolomite; and some fragments of sandy-looking dark greenish gray that might be glauconite. Base of GREENFIELD DOLOMITE.
17. 110-120 ft. *White*, fine grained to finely crystalline and saccharoidal dolomite. Fragment of a coral (*Favosites*?). Top of HUNTINGTON DOLOMITE.
18. 120-130 ft. Several flat chips of fine grained medium gray dolomite. Look as though slickensided.
19. 130-140 ft. Like 18. Finely crystalline.
20. 140-150 ft. Very small pieces, angular, light brown, dense, sharp-edged. Dolomite.
21. 150-160 ft. Dense, fine grained, hard, medium gray dolomite. Slight effervescence. A few lighter colored particles.
22. 160-170 ft. Same as 21.
23. 170-180 ft. Same; but with fragments of sandstone with calcareous cement.
24. 180-190 ft. Some like 23; but with much white crystalline dolomite. One large fragment very coarse, granular and porous.
25. 190-200 ft. Like 21 and 22.
26. 200-210 ft. Same.
27. 210-220 ft. Same; but drusy, with calcite and stylolites. Fragments of *Halysites*, *Favosites* and crinoids.
28. 220-230 ft. Small pieces. Mostly lighter colored. Stylolites.
29. 230-240 ft. Almost *white*, slightly buff, porous, finely granular dolomite. Numbers *18 to 28 are interpreted as reef rock.*
30. 240-250 ft. White, mottled with gray, crystalline. Some pieces very porous. Mostly flaky-crystalline.
31. 250-260 ft. White, rather fine grained.
32. 260-270 ft. White to light gray, flaky, coarsely crystalline. Slight effervescence. Crinoid fragment.
33. 275-280 ft. White, flaky-crystalline. Good fragment of crinoid stem.
34. 280-290 ft. White or very light gray. Flaky crystalline.
35. 290-300 ft. Three large pieces of drusy, porous, finely granular, crystalline, light brownish gray dolomite. Fair effervescence.
36. 300-310 ft. Almost *white saccharoidal* dolomite.
37. 310-320 ft. Mostly large sharp-edged flakes of dense, light gray dolomite. Some white porous dolomite. Fair effervescence.
38. 320-330 ft. Light gray to almost white, flaky, crystalline dolomite.
39. 330-340 ft. Mostly very light gray saccharoidal dolomite. One piece of finely granular brown dolomite.
40. 340-350 ft. Very light gray to white, flaky, coarse dolomite. Porous. Fairly good effervescence.

41. 350-360 ft. Light gray to white, coarse flaky dolomite.
42. 360-370 ft. Very light gray, coarsely crystalline, flaky.
43. 370-380 ft. Mostly white, saccharoidal dolomite. Good effervescence.
44. 380-390 ft. Same as 43.
45. 390-400 ft. Same.
46. 400-410 ft. Slightly darker and more flaky. Stylolites.
47. 410-420 ft. Very light gray to white, splintery, porous.
48. 420-430 ft. Very light brown granular, saccharoidal dolomite. Fair effervescence.
49. 430-440 ft. Light brownish gray, saccharoidal. Good effervescence.
50. 440-550 ft. Dense, finely granular, light brownish gray. Angular fragments.
51. 450-460 ft. *White*, saccharoidal, fair effervescence. Looks like typical Huntington dolomite.
52. 460-470 ft. Pure white dolomite.
53. 475-485 ft. White dolomite, mottled with gray to blue.
54. 485-495 ft. Buffish white, very finely pulverized, soft dolomite.
55. 495-505 ft. White, saccharoidal dolomite.
56. 505-515 ft. White dolomite.
57. 515-520 ft. Light gray, dense, porous, flaky, dolomite. Very slight effervescence.
58. 520-525 ft. White to gray, mottled, saccharoidal dolomite. Crinoid fragment.
59. 525-535 ft. White to gray, very saccharoidal dolomite.
60. 535-545 ft. Coarsely saccharoidal, white, porous. Finely pulverized. Evidently very soft.
61. 545-555 ft. Slightly grayer, very saccharoidal dolomite.
62. 555-565 ft. Light bluish gray, dense, *very cherty*, hard splintery limestone. Light blue to white chert very abundant. Top of LISTON CREEK LIMESTONE.
63. 565-575 ft. Very *cherty* light gray limestone, with white, strongly effervescent particles. Chert light gray.
64. 575-585 ft. Dark gray, splintery, prous dolomitic limestone. Much light gray *chert*.
65. 585-595 ft. Same, but with less *chert*.
66. 595-605 ft. Medium gray, spintery, *cherty* limestone.
67. 605-615 ft. Medium gray, *very cherty*, dense, splintery limestone.
68. 620-630 ft. Dark gray, porous, dense limestone. Very muddy sample. Three pieces of blue soft shale. Probably top of MISSISSINEWA SHALE. This last screw evidently just touched the top of the shale.

These detailed well sections may be summarized as follows:

Well No. 1 reaches a thin remnant of *Greenfield* dolomite somewhere between 100 and 110 feet. At 110 feet it enters pure, almost white, granular, fine grained dolomite of typical Huntington or Guelph character. This white dolomite, often very saccharoidal, persists with a few slight alternations of browner or gray dolomite, to a depth of 280 feet, where a grayish brown to brown somewhat cherty dolomite set in and continues to 380 feet. This 100 foot bed has the lithology of the *New Corydon* formation of Cumings and Shrock (1928). From 380 to 400 feet the samples show considerable blue, shaly rock. This evidently represents an expansion of the shaly streak sometimes seen on the outcrop at the

base of the New Corydon. Below this level, down to 560 feet, the rock is coarsely saccharoidal, granular, very white and typical of the *Huntington* as seen in the outcrops of eastern Indiana. At 560 feet the drill enters a fine grained, light gray, very dense, cherty, splintery rock of typical *Liston Creek* lithology. This persists to the bottom of the well at 640 feet.



Thickness of Huntington dolomite (and New Corydon member) 450 feet. Thickness of Liston Creek limestone 80 feet. Thickness of Niagaran 530 feet.

Well No. 2 reaches a light brown, fine grained dolomite at about 70 feet, and penetrates the same rock to 110 feet. This 40 feet of brown dolomite has the characteristics of the *Greenfield* dolomite of Ohio, and is so correlated. At 110 feet the well enters a very white, fine grained to finely crystalline, saccharoidal dolomite, which is evidently the top of the *Huntington* formation. A fragment of coral, probably *Favosites*, occurs in sample No. 17. Below this level for 110 feet, the samples are of an unusual character, usually light gray to light brown, dense, flaky, sharp-edged, and sometimes slickensided. Stylolites are common, and fragments of corals and crinoids appear in the samples, notably No. 27. These cuttings are quite different from those at the corresponding levels in well No. 1, and can only be interpreted as reef-core rock. From the known abundance of reefs in the Huntington formation in Indiana and Ohio, such an interpretation is perfectly admissable; and the lithology of samples 18 to 28 clearly supports it. At 230 feet the well enters almost white saccharoidal dolomite, and this persists with some alternations of gray and denser rock to 450 feet, below which to 555 feet the cuttins show white, coarsely granular typical Huntington rock. Some of the samples in this interval suggest the New Corydon member; but the New Corydon lithology does not persist as it does in well No. 1. Evidently actual reef conditions or proximity to a r eef are influencing the rock in this well down through

practically the entire Huntington interval. At 555 feet the drill penetrates very cherty, dense flaky rock of typical *Liston Creek* character, and this persists to the bottom of the well. The last sample, No. 68, is very muddy, with several fair sized chips of shale, and evidently the drill just touched the top of the *Mississinewa* shale.

0′		Well cap at 754.5 ft. A. T.
	70′	Glacial drift.
70′		Top of brown Greenfield dolomite.
	40′	Greenfield dolomite.
110′		Base of Greenfield. Top of Huntington.
	120′	Reef rock, except upper 10 feet.
230′		Base of reef-core rock.
	325′	Huntington rock, with suggestions of the New Corydon member.
555′		Base of Huntington dolomite. Top of Liston Creek limestone.
	75′	Liston Creek limestone.
630′		Bottom of well. Base of Liston Creek limestone. Top of Mississinewa shale.

Thickness of Greenfield 40 feet. Thickness of Huntington (including New Corydon member) 445 feet. Thickness of Liston Creek limestone 75 feet. Thickness of Niagaran 520 feet.

Two wells at Fort Wayne, recorded by Logan (1926, p. 25), give 30 and 34 feet of Waterlime (Greenfield) and 570 and 571 feet of Niagaran limestone and shale. These penetrate the Mississinewa shale, for they go on down to the Trenton, which is reached at 693 and 650 feet below sea level. How much of the Mississinewa shale is included in the so-called Hudson shales of these well sections it is impossible to determine. If Logan's determination of the top of the "Hudson" is correct, there would be only 40 or 50 feet of Mississinewa. This is probably the shale so commonly reported as "Rochester" and "Clinton" in the Michigan and Ohio wells.

A well drilled in Perry township, Allen county, Indiana, gives, according to Logan (*loc. cit.*) 749 feet of limestone, underlain by 430 feet of "white shale," and the latter by 240 feet of black shale, down to the Trenton. Part of the stated thickness of limestone is undoubtedly Greenfield. The "white shale" might be in part Mississinewa, which in wells in the Wabash valley region is sometimes reported by the drillers in this way. This well is about 14 miles north of the two detailed above. The Trenton is reached at 856 feet below sea level.

A well in Maumee township, Allen county, 18 miles northeast of the Fort Wayne wells gives: drift 48 feet, limestone with a little shale and "red rock" 554 feet, shale 715 feet, to the Trenton. The base of the Mississinewa cannot be fixed in any of these wells.

The thickness of the Huntington dolomite, which correlates with the Racine and Guelph (Port Byron) of Illinois and Wisconsin, and with the Springfield and Cedarville (Durbin) and "Guelph" of Ohio, is accurately determined as 450 feet in the Fort Wayne wells. Thie thickness of the Liston Creek is 75 to 80 feet, if the shale shown in the last sample (No. 68) of well No. 2 is the top of the Mississinewa. These wells were drilled for water and evidently stop at the top of the impervious Mississinewa formation, after penetrating the porous dolomites. The thickness of the Mississinewa cannot be determined in any of the northeastern Indiana wells. Probably part of this formation is confused in the various well logs with the underlying Cincinnatian shales. Within the Huntington dolomite, the cherty New Corydon dolomite forms a bed about 100 feet thick.

At Huntington, Indiana, the base of the Liston Creek limestone is 680 feet above sea level, at the Erie quarry east of the city. At Fort Wayne it is 125

Fig. 1—Key map of the Michigan Basin region.

feet above sea level. The Niagaran therefore descends 555 feet between Huntington and Fort Wayne, or about 25 feet per mile. In this same distance the Trenton descends about 440 feet. This is a rather unexpected result, and probably indicates thinning of the Mississinewa formation to the northeast. In the wells in Huntington county, and elsewhere in the Wabash valley region, the Mississinewa is commonly reported as limestone. For example, in the many logs listed by Logan (1926) from near Warren in southeastern Huntington county most of the 400 feet or more of "limestone" is below the top of the Mississinewa, since that formation outcrops along the Salamonie river to within a short distance of Warren. The more detailed logs given on page 269 of Logan's report indicate from 240 to 280 feet of limestone beneath the 20 feet or so of drift, and underneath this "white shale" or "white mud" for as much as 160 feet. In other logs this is all included as "limestone." What this "white mud" is geologically it would be difficult to say. If it is Cincinnatian, that division would be given a thickness of over 700 feet in Huntington county wells, which is comparable with its reported thickness in the Fort Wayne wells, and more in keeping with what would be expected. On this supposition, the eastward thinning of the interval between the base of the Liston Creek and the Trenton is due to the reduction of the Mississinewa formation.

Bownocker (1903) has summarized the well data of Ohio in his report on oil and gas in Ohio. A well at Findlay (*op. cit.*, p. 69) gives 275 feet of Niagara and "Clinton" limestone and shale, 47 feet of red "Medina" shale, and 762 feet of Cincinnatian. Greenfield dolomite outcrops at Findlay, so that this figure represents the entire thickness of the Niagaran of that locality. "Lower Helderberg" (Greenfield), Niagara and "Clinton" limestones are 330 feet thick at Lima. Forty feet of "Clinton shale" is reported below the limestone and above so-called red Medina shale. A well at Beaverdam, near Lima, reports 105 feet of "Clinton shale." These wells report over 800 feet of Cincinnatian shales. A well at Celina gives 135 feet of Niagara limestone and 15 feet of Niagara shales, underlain by 43 feet of "Clinton" limestone and 20 feet of "Medina shales." This "Clinton" may be the Bassfield limestone, and the "Medina" the Elkhorn formation of the Richmond. The upper 85 feet of the Niagara is described as yellow and white, and is undoubtedly Huntington, which outcrops a few miles west of Celina. The lower 50 feet of the Niagara is described as drab and of various shades. This might be the Liston Creek limestone. The writer has reexamined the quarry at Lewisburg, Ohio, 50 miles south of Celina, and is convinced that Prosser's (1916) "Osgood" and "Laurel" are not correlates of these well-known southern Indiana formation; but feather edges of the Mississinewa and Liston Creek formations of the northern Indiana area. The two have a combined thickness of only 13 feet at Lewisburg, whereas in the Wabash valley their combined thickness is some 300 feet. If the above interpretation of the Celina well is correct, their combined thickness there is 65 feet. The evidence of the wells is thus entirely consistent with the southeastward thinning of the lower Niagaran described by Cumings and Shrock (1928, 1928a).

Wells in northwestern Ohio also report Niagara and "Clinton" shales below Niagara limestone. At Bowling Green in Wood county, Bownocker (p. 59) reports 108 feet of Niagara and "Clinton" limestones and shales, below 167 feet of limestone. At Rollersville, in Sandusky county, 30 miles west of Sandusky, he reports (p. 74) gray and white limestone 300 feet (Huntington), blue limestone 20 feet (Liston Creek), white slate 2 feet, brown limestone 21 feet and light slate

20 feet. This lower 43 feet may be Mississinewa. Below this he has 100 feet of "Clinton" and 80 feet of "Medina." Interpreting this "Medina" shale as Queenston, this well contains 760 feet of Cincinnatian. A well at VanWert Van Wert county, (p. 98) has 185 feet of Niagara limestone and 15 feet of Niagara shales.

Richard A. Smith (1914) reports on the deep wells in Michigan, including also several in Ontario peninsula. A well at LaSalle in Monroe county, Michigan, (*op. cit.*, p. 76) has "Niagara (Guelph and Lockport)" 490 feet, described as "white lime"; and "Rochester shale and Clinton" 165 feet, described as "blue shale and shells." From a well at Strasburg, near LaSalle, he reports (p. 77) "Guelph and Lockport" 410 feet. Judging from his detailed description, based on the examination of a set of samples by Dr. A. C. Lane, this mass is very much like the 450 feet of Huntington in the Fort Wayne wells, and even includes 80 feet of " 'very hard,' brown, sandy looking" dolomite which may be interpreted as New Corydon. Below this he reports 70 feet of "Rochester shale?" and 130 feet of "Clinton," described as "ferruginous dolomite and limestone." There is nothing in this well that can be interpreted as Liston Creek. From the Carman well at Petrolia, Ontario, southeast of Port Huron, he reports 275 feet of "Guelph and Niagara lime" (p. 54), 60 feet of "Rochester (Niagara) shale," described as "red and dark," 90 feet of "Clinton" and 275 feet of "Red Medina." The top of the Guelph is 1,438 feet below sea level. Williams' well sections (1919, fig. 4) give only a little over 100 feet of Medina at Tilbury, just east of Lake St. Clair, and Beachville, near Woodstock, Ontario. This "red Medina," therefore, must be largely Queenston shale, of which Williams indicates several hundred feet in the sections mentioned. Williams' Tilbury section indicates about 300 feet of Lockport and Guelph, and 50 feet of Rochester shale, as scaled from his graph. Sections along the north shore of Lake Erie, at Port Burwell, Port Ryerse, Walpole, Dunnville and Bertie, also show Rochester shale up to 40 feet or so in thickness. From Hamilton, Ontario, northwest, however, the Rochester shale and Clinton completely disappear. Whether the "Clinton" reported by Smith and Williams is Clinton or Brassfield (Cataract) cannot be determined. Clinton has not been certainly identified in the Michigan Basin region, while Medinan (Brassfield, Cataract, Mayville, etc.) is known to occur widely.

In southwestern Michigan Smith (p. 177) reports on a deep well at Dowagiac, Cass county, which reached nearly to the Trenton. At 1,100 feet the drill entered light gray dolomitic limestone, somewhat cherty. The next 580 feet are referred to the Lockport and Guelph. The lower 70 feet contains considerable silica and clay, and is described as "white to gray fine grained limestone" and "creamy white marly limestone." Overlying this is 70 feet of "grayish white to gray fine grained limestone" containing "flint" (chert). This is probably the Liston Creek (Waukesha) limestone. The lower 70 feet may represent the Joliet limestone. Forty feet of "Rochester" is reported below the Niagara limestones. This may belong to the Cincinnatian.

Well No. 2 at St. Ignace in the Upper Peninsula (Smith, p. 243) penetrates 656 feet of "Niagaran," without reaching the bottom of this division. The upper 60 feet is described as light dolomite, and the next 15 feet as "white sandy dolomite." Below this is 7 feet of "hard mixed cherty dolomite." This probably represents the top of the Coral Beds or Manistique. The upper 75 feet may be referred to the Engadine (Racine). The lower 450 feet or more should be in the Burnt Bluff (Byron) formation of Ehlers (1921).

In Wisconsin the Racine-Guelph dolomite is underlain by the Waukesha cherty limestone in the southeastern part of the State, and by the cherty Coral Beds in the Door Peninsula region. The Waukesha and the Coral Beds are thin bedded, cherty, slabby, dense, gray limestones, like the Liston Creek limestone of Indiana, and contain the same Louisville coral fauna, characterised by species of *Alveolites, Favosites, Halysites, Thecia, Strombodes, Syringopora, Cladopora, Eridophyllum, Lyellia, Heliolites, Plasmopora* and *Zaphrentis*. These cherty coral beds are also present throughout the Upper Peninsula of Michigan, and were extensively collected from by Rominger, especially at Point Detour, Chippewa county, and on Drummond Island. Ehlers (1921) has redefined the term Manistique, which was proposed by R. A. Smith (1916) for the great mass of dolomites below the Engadine dolomite, and made it apply to these coral beds. The coral beds are also known on Manitoulin Island, where, as at Coral Hill, they contain the corals in extraordinary abundance. M. Y. Williams (1919) mentions corals in the lower part of the Lockport at Cabot Head and Owen Sound in Bruce Peninsula, Ontario. The writer visited the principal sections in Ontario, during the past Summer, and found the coral beds in typical development at Isthmus bay, just north of Lion Head, and at Dyer bay. At Isthmus bay 35 feet of thin layers abounding in corals, and containing a little chert, are overlain by the massive Lockport dolomite. In the lower part of these coral beds *Pentamerus oblongus* is very abundant. At Dyer bay 64 feet of thin coral beds rest on a dense very evenly jointed, brownish gray dolomite, much like the Byron of Wisconsin. The coral beds are capped by massive Lockport dolomite. No well developed coral beds were seen south of Isthmus bay and Lion Head; though at Owen Sound there are some corals and the lower part of the Lockport is thinner bedded than the main mass, and contains *Pentamerus oblongus* abundantly. This brachiopod also occurs in abundance at the base of the coral beds in Michigan and Wisconsin. The coral beds with their characteristic Louisville corals do not occur in New York and the Niagara peninsula.

The last statement raises the question whether any of the typical Lockport of New York is an old as the coral beds. Williams (1919) regards the Lockport as an invasion from the north, and intimates that the lower portion of the more northwestern secions may be older than the New York Lockport. The Lower Shelby or first Guelph fauna of Clarke and Ruedemann (1903) occurs well down in the Lockport. With the exception of a few stray Guelph species in the Liston Creek reef at Markle, Indiana, and in the reefs of the Lower Coral Beds of Wisconsin, the Guelph fauna first appears in the Racine of Wisconsin and Illinois and in the lower Huntington of Indiana and Ohio. This would correlate the New York Lockport with the Racine, in accordance with the arrangement indicated by Ulrich (1911, pl. 28) and Savage (1926, p. 533); though in the text, Ulrich (p. 561) places the Racine "in the hiatus between the Rochester and the Lockport." From Ulrich's correlation of the Louisville *above* the Guelph there must be complete dissent, as also from Schuchert's statement (1910, p. 534) that the corals of the Siluric have little stratigraphic value. Schuchert places the Racine above the Lockport.

In the writer's view the coral beds (Louisville, Liston Creek, Waukesha, Manistique as restricted, etc.) constitute the most reliable and easily traceable horizon in the entire Niagaran. In the Michigan Basin region they constantly occur immediately beneath a very massive, saccharoidal, light gray, pure dolomite, variously known as Racine, Engadine, Lockport and Huntington (lower).

These coral beds extend as far east as northwestern Ohio and Lion Head in Bruce Peninsula; but no farther. The massive overlying dolomite extends much farther east and south, namely nearly to Hamilton, Ontario, and beyond Cedarville, Ohio. To the westward and northward it is coextensive with the coral beds.

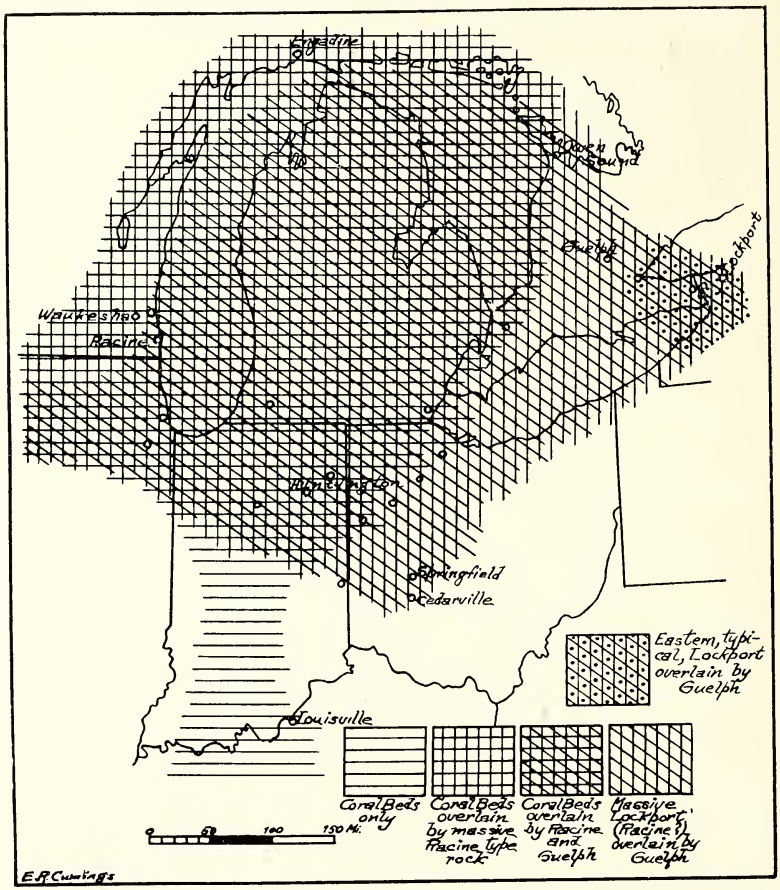


Fig. 2—Map of the Michigan Basin region, showing general distribution of the coral beds, Racine and Guelph formations. Boundaries extended somewhat beyond present area of outcrop.

The exceedingly massive, light gray mottled saccharoidal dolomite of Bruce Peninsula, overlying the coral beds, resembles the Engadine dolomite of the Upper Peninsula of Michigan to an astonishing degree, and weathers in the same way into enormous boulders, which thickly besprinkle the landscape, as any one who has ever driven the road to Tobermory will agree. This massive gray dolomite persists southeastward to about Nelson, a few miles north of Hamilton, Ontario; abounding in coral reefs, as at Milton and Rockwood, and often becoming a mass of crinoid fragments. East of Hamilton, the only thing that at all resembles this great dolomite lithologically is the Gasport dolomite

(or limestone) at the base of the Lockport. The chert beds and "Barton beds" of Dundas have nothing corresponding to them farther north—so far as lithology goes. Evidently the muddy waters of Hamilton were too much for the corals and crinoids that provided the material of the massive dolomites from Nelson to Tobermory.

In the laying down of this massive gray dolomite, after the time of the cherty coral beds, the teeming life of the Niagaran sea assumes complete mastery of the sedimentation and builds a formation, the Racine-Guelph, entirely derived from its own exuviae. The Racine is the foundation of the great mass of which the Guelph is the superstructure. They are both comprised within the Huntington of Indiana, 450 feet in thickness; and this name might appropriately be used in this sense throughout the Michigan Basin region. "It is a single, well-defined episode, ushered in by an increasing spread of the coral seas at the close of Liston Creek time....." (Cumings and Shrock, 1928a).

The well sections discussed above, and the field studies of the past few years around the rim of the Michigan Basin, suggest some interesting conclusions in regard to the formations *below* the coral beds.

In Indiana the coral beds (Liston Creek) are underlain by an argillaceous limestone, the Mississinewa shale, containing 50 per cent or more of noncalcareous matter (Cumings and Shrock, 1927, 1928, 1928a). Its exposed thickness is 75 feet; but wells in the Wabash valley indicate at least 100 and probably 200 feet or more of this formation. The interval between the base of the Liston Creek limestone and the top of the Cincinnatian shales is at least 250 feet. In the well logs this is often reported as limestone—sometimes as white shale. In the outcrop, more resistant limy layers are sometimes seen, as at Jalapa on the Mississinewa river. It is not unlikely that the formation as a whole is composite, consisting of limestone and shale members. Some of the more detailed well sections suggest this. Toward the northwest the formation becomes more calcareous.

In the Chicago area, an even bedded, light colored, impure limestone, the Joliet, underlies the coral beds (Waukesha). Some 80 feet of this formation is exposed in the quarry at Joliet. It has been described and named by Savage (1926). It is correlated by Cumings and Shrock with the Mississinewa shale of Indiana. Its fauna is not especially diagnostic; but the fine graptolite fauna of the Mississinewa, and a large list of species recently collected by the writer from a reef in the Mississinewa, are sufficient to correlate at least the upper part of that formation with the Rochester shale of New York. (See Shrock, 1928). The Joliet is underlain by the Kankakee (Brassfield) formation of Medinan age.

In Wisconsin the Byron formation, an even bedded, perfectly jointed, light colored, often rather thin bedded dolomite, with some lithographic bands, and occasional argillaceous beds, underlies the coral beds (Waukesha, Coral Beds). Underneath this formation is the Mayville vesicular, rough, massive dolomite. These two formations give rise to the conspicuous cuesta east of Lake Winnebago and Green Bay. They have been traced into the Upper Peninsula of Michigan by Ehlers (1921), Verwiebe (1927) and the writer; where the Byron has been renamed the Burnt Bluff formation by Ehlers. The Byron of Upper Michigan is exactly like the Byron of Wisconsin. The Mayville has been identified on Drummond Island by Verwiebe. In the Seaman quarry at Drummond village, much of the Byron is somewhat argillaceous, and the weathered material on the dump looks like Mississinewa shale.

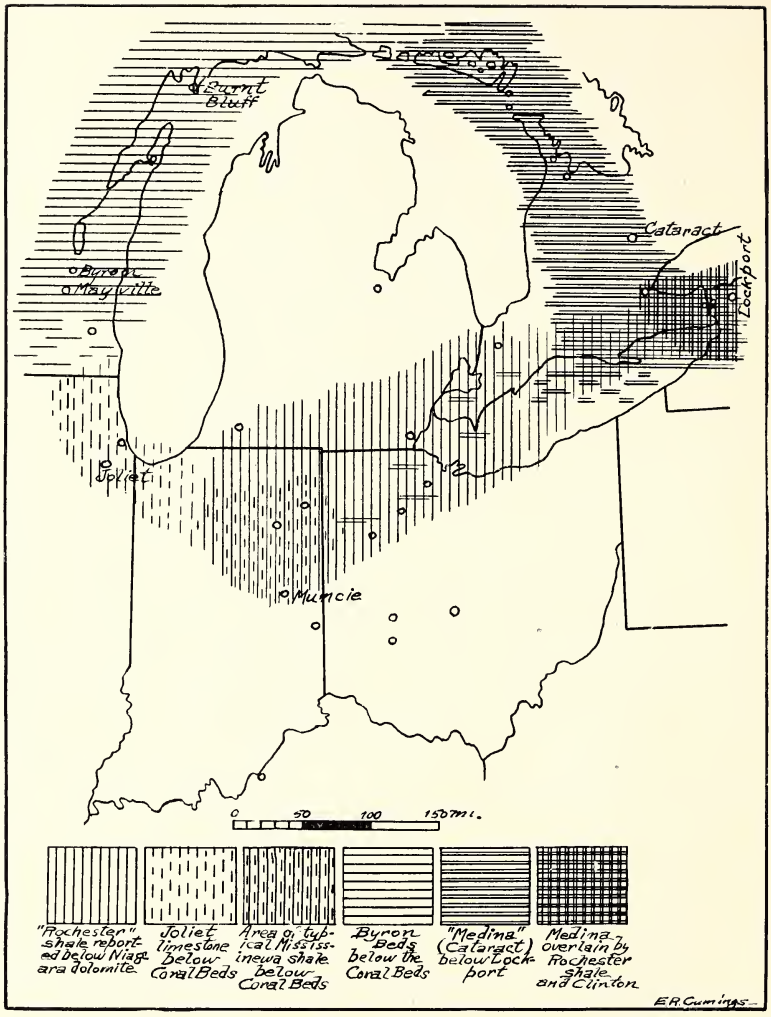


Fig. 3—Map of the Michigan Basin region showing general areas of the Mississinewa, Joliet, Byron and Mayville and Cataract (Medina) formations. Boundaries extended somewhat beyond present area of outcrop.

The Rochester shale of New York disappears at Dundas, Ontario, and north of there the Lockport rests first on the Clinton limestone, and then, beyond Milton, on the Medina (Cataract) shales. The Medina formation (Cataract) has been traced across Ontario Peninsula by Williams and others, into Manitoulin Island, becoming first more shaly, and finally more calcareous, till on the Island there are several heavy beds of dolomite, of which the Manitoulin dolomite is the most important.

Wells along the north shore of Lake Erie and in the region of Lake St. Clair indicate that the Rochester shale persists to the westward. It is reported from

wells in southeastern Michigan and northwestern Ohio. The "Medina shale" beneath it is referred to the Cabot Head shale by Williams.

The facts stated in the preceding summary are expressed graphically on the accompanying map, (fig. 3). They are mostly facts of common knowledge among

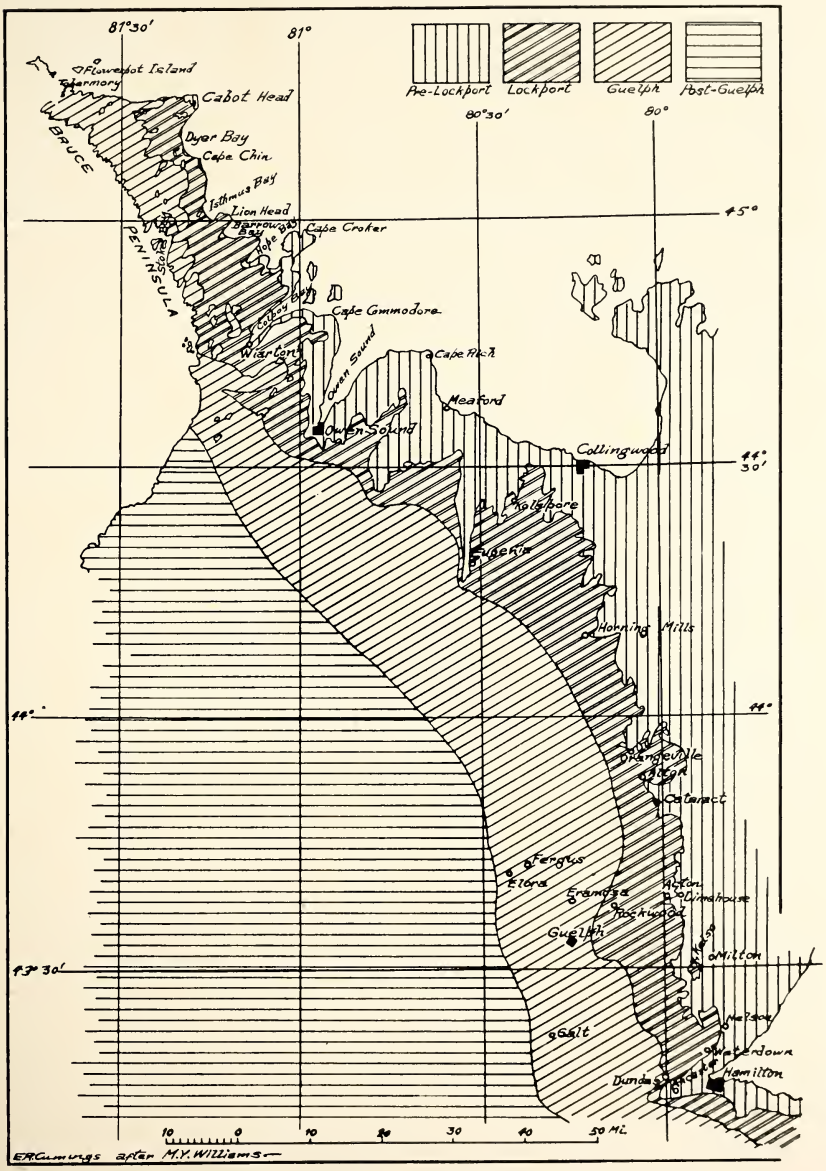


Fig. 4—Map of a portion of Ontario, including Bruce Peninsula, showing distribution of the Lockport and Guelph.

geologists familiar with the region. It is in their interpretation that opinions vary. For example, the Mississinewa formation, so far as recognized at all heretofore, has been placed in the Lockport division (so, Kindle and others). The Joliet is placed at the base of the Lockport by Savage (1926). The Mayville is correlated with the Clinton by Ulrich (1923) and others, and with the Lockport by Ulrich (1911); and with the Edgewood by Savage (1926). The Byron is placed in the Lockport by most geologists; but it is correlated with the Brassfield by Savage (1926). Verwiebe's chart (1927, p. 313) is difficult to interpret, but appears to indicate that the lower part of the Byron is to be correlated as pre-Lockport. He correlates the Mayville with the Manitoulin dolomite (p. 319). Paleontologic evidence of the age of the Byron is singularly meager.

All of these formations are older than the coral beds, which are regarded by the writer as very early Lockport, and indeed older than the typical Lockport of New York. None of them, therefore, is Lockport. The pre-coral beds to the south (Illinois, Indiana, Ohio) are probably Rochester. They are underlain by Medinan. The Mayville and the Byron are believed to be western calcareous equivalents of the entire Cataract formation of Ontario and Manitoulin Island, and may rise even into Clinton and Rochester horizons.

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SILURIAN REEFS NEAR TIFFIN, CAREY AND MARSEILLES, OHIO

E. R. CUMINGS, Indiana University

In the paper by Cumings and Shrock (1928, p. 614) on Niagaran coral reefs of Indiana and adjacent States, reefs are indicated, on the authority of Winchell (1873), near Tiffin and Carey, Ohio. Recently the writer visited the localities mentioned by Winchell, and confirmed the surmise of 1828 that these structures are reefs.

In his report on Seneca county, Winchell described (p. 615) abnormal dips along the Sandusky river, between Tiffin and Fort Seneca. On page 614 he says, "Throughout the most of this distance the dip of the formation (Niagara) is from five to ten degrees toward the southwest, but with various flexures and undulations in all directions." On page 615 these flexures are described in detail. Winchell did not suspect that these are reef structures. He mentions reversed dips as high as 10 degrees.

This locality was visited by the writer on Oct. 10th, 1929, and studied rather carefully, with the following results.

A few small outcrops may be seen within the city of Tiffin along the edge of the river, below the concrete retaining wall; but nothing of consequence. At the first dam north of Tiffin the dip is slight and the layers of rock not very massive. One-fourth mile north, massive beds of light brown somewhat banded dolomite (Greenfield) are exposed in the east bank of the river, underlain by Niagara (Guelph) to river level. The contact is exposed, and is clean-cut.

At the second dam, and concrete bridge, one mile north of Tiffin, the upper layers, at the east end of the bridge, are thin, even, saccharoidal dolomite, of light gray color. They dip 5 to 6 degrees upstream (south). North of the bridge the dip changes to north (down stream). Under the bridge very massive ledges of ash-colored, saccharoidal, sandy dolomite are exposed in the bed of the river. These ledges are very rough looking, and are probably reef rock. Just north of the west end of the bridge, massive unstratified, very rough, ragged, much brecciated dolomite, full of stromatoporoids, is exposed in the bed and bank of the river. *Favosites* is also common. This is typical reef-core rock. The overlying layers here dip to the southeast. The reef is apparently a ridge running in a northwest-southeast direction across the river.

Four-tenths of a mile north of this bridge the layers rise again, on the south side of the river opposite the power house, to a dip of 4 degrees south; but within a few rods reverse to a north dip. The rock under the center of this arch is irregular, but not very massive, and is probably just above the core of a reef.

A similar structure appears in the west bank of the river at the old timber dam two-tenths of a mile farther north; and another with very slight dips at the old mill two miles north of Tiffin. At the quarry in the east bank of the river, about two and one-half miles north of Tiffin, the dip is about 2 degrees toward the river (west). Here the floor of the quarry is a massive, light blue brecciated rock, with many druses of well crystallized calcite. It is not certain that this is reef rock.

North of this point the river flows over rock for some distance, but with only slight undulations of the layers.

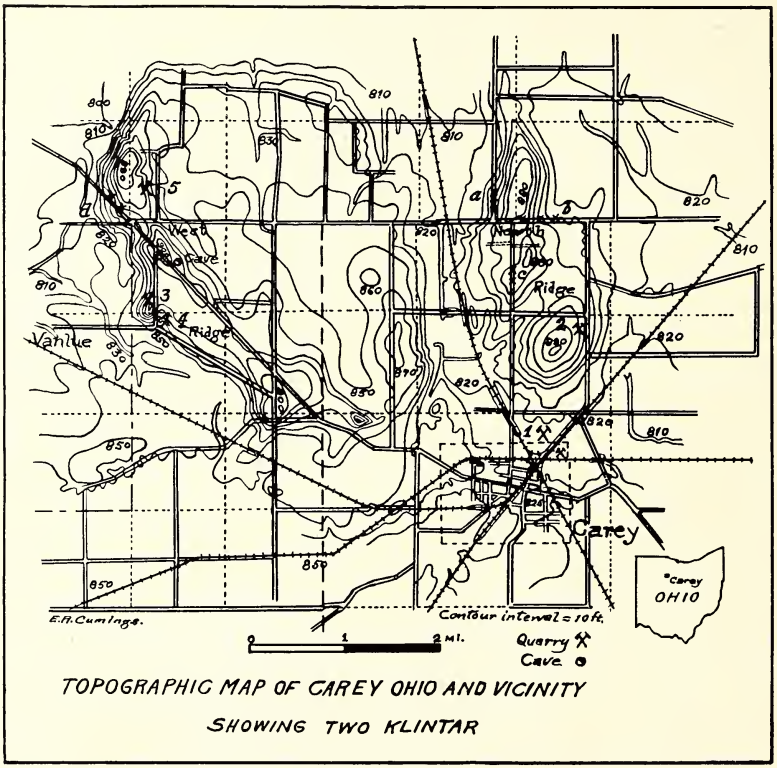

Fig. 1—Topographic map of Carey, Ohio, and vicinity; showing location of the "Limestone. Ridges," quarries and other outcrops.

In his report on Wyandot county Winchell (1873, pp. 625-639) described in some detail the peculiar "limestone ridges" north and northwest of Carey, Ohio. On page 627 he says, "The *Niagara limestone* has, near Carey, an unusual and somewhat remarkable exposure. The surface of the country for many miles in every direction is flat, without exposure of rock. At this point the Niagara swells up suddenly in two separate mounds or ridges, which rise so obtrusively that the drift has been in many places entirely denuded. They rise to the height of forty or fifty feet. They are each about five miles long, and are so situated

toward each other, and in relation to the direction of the natural drainage, that they enclose the marsh known as Big Spring Prairie. They are distinguished as the *North Ridge* and the *West Ridge*." On page 628 he gives a rough sketch indicating the position of the ridges, Big Spring Prairie, and the quarries around the edges of the ridges. "In these [quarry] openings the stone appears very different from that seen in bare places higher up the ridges and on their summits, and the dip is uniformly toward the low ground, whatever the position of the quarry." Dips as high as 18 degrees are mentioned (p. 629). Winchell explains these structures (p. 631) as due to a "concretionary and crystallizing force..... which, working from below, caused the even beds of deposition to swell upward over the growing mass or masses.....the even, friable beds seen in the quarries about their flanks having once been continuous over their summits, but, unable to resist the forces of the glacial epoch, were denuded down to the more enduring rock."

These limestone ridges are mentioned by T. A. Bonser (1903) in his paper on an "Ecological Study of Big Spring Prairie, Wyandot County, Ohio," but without details of the geology. He gives maps showing the ridges and the prairie. Alfred Dachnowski (1912) also mentions the ridges in his report on the peat deposits of Ohio, and states the depth to bed-rock in the prairie between the ridges and to the north of the West Ridge. Outside of Winchell's report there seems to have been no further description of the geology of these exceedingly interesting structures.

The writer visited the locality on Oct. 11th, 1929. Most of the quarries mentioned by Winchell have long since been abandoned; but several newer quarries are in operation; and numerous exposures of rock may be seen along several of the roads that traverse the ridges.

The most interesting and significant exposure is in a recently abandoned quarry a mile north of the large quarry of the National Lime and Stone Company in the north edge of Carey, and just west of the north-south road. (See quarry No. 2 on map, fig. 1). The floor of this quarry is very massive, unstratified, much brecciated, very fossiliferous reef-core rock, the surface of which dips several degrees toward the road (east). The thinner layers above show a slight east dip in the southwest corner of the quarry. This reef rock is full of stromatoporoids, corals (*Favosites*, *Halysites*), and beautiful cross-sections of a large *Megalomus*. There are also many large gastropods. The owner of the farm says that all along the ridge the layers slope down hill, and that in plowing down hill, the plow point "catches the edges of the layers"; but that in plowing up hill it rides smoothly over them. A similar ragged dolomite is seen at the points marked *a b c* , two miles north of Carey.

The National Lime and Stone Company has very large quarries on either side of the railroad tracks in the north edge of Carey. The north quarry (No. 1, fig. 1) is in the Guelph dolomite, except at the southeast corner, where the Greenfield dolomite overrides it. The contact is clear-cut and slopes about 5 or 6 degrees to the south. No Greenfield is seen along the north and west sides of the quarry. The north wall, in the northwest corner of the quarry, shows an east dip, but on the stripped surface just west, the dip is westerly. Thinner layers, due in part to westhering, cap the west side. Below these and forming the main wall of the quarry, the rock is exceedingly massive, strongly brecciated, with many fragements of large size, and filled with fossils. *Favosites*, *Halysites* (some very large colonies), gastropods, crinoids, many stromatoporoids, algae (?), and *Megalomus* are the common forms. Portions of the rock are composed entirely

of crinoid segments. It will be seen from the map (fig. 1) that this quarry is on the extreme southern margin of the North Ridge.

Three quarries, the so-called Wyandot Indian cave, and various other outcrops were visited along the West Ridge. These quarries (3, 4 and 5, fig. 1) are in the Greenfield dolomite, except a very small exposure of the Guelph in the east end of No. 3. In numbers 3 and 4 the Greenfield is filled with stromatoporoid bioherms (so-called reefs), which give it an extremely irregular appearance. Some of these are several feet in diameter. There is much brecciation. In the east end of No. 3, near the crusher, the Guelph dolomite, filled with *Favosites*, rises in a cone-like mass of very ragged, brecciated, massive gray rock, extending about half way up the quarry wall. It is overlain with very sharp contact by thin layers of Greenfield dolomite, which slope away more or less in sympathy with the surface slope of the Guelph. This very interesting contact strongly reminds one of the similar abrupt contacts of the Kokomo and Kenneth limestones with the Huntington limestone west of Logansport, Indiana (See Cumings and Shrock, 1928a).

Wyandot Indian cave, managed by Mr. Fred C. Hess, is in the crest of West Ridge, four miles northwest of the center of Carey, on State road No. 15. It is a small but very interesting cave. It was evidently formed before the Glacial Period and partially silted up during that time. Most of the rock exposed in the cave is Greenfield dolomite, very deeply weathered, and filled with irregular bioherms of stromatoporoids, so that the mass has an incomprehensibly tangled and irregular structure. There is intense brecciation. At a few points the Guelph appears to be exposed, but the weathering is so great that this could not be determined with certainty. It is evident that in places the Greenfield caps the ridge. A mile northwest of this point, however, the Guelph appears to extend to the top of the ridge, as it does also on the North Ridge. Quarry No. 5 is in the Greenfield dolomite, and shows much less irregularity of structure than numbers 3 and 4.

It is evident that the two ridges at Carey contain a core of very massive, unstratified, coarse, brecciated, highly fossiliferous Guelph dolomite, rising in numerous places to the crests of the ridges; but flanked, and in some places capped, by unconformable Greenfield dolomite. The flanking rock, and the Guelph itself, wherever the bedding is distinct enough to show it, dip outward toward the low ground, as Winchell long ago pointed out. There can be no doubt that these ridges are klintar, due to the superior resistance of the reef rock of which they are composed. These klintar rise 80 to 100 feet above the Big Spring Prairie on the north and west; and according to the figures of Dachnowski (1912), 90 to 114 feet above the level rock floor beneath the prairie. They stand 40 to 50 feet above the general level of the glacial plain to the south.

In the same report (1873, pp. 631-632) Winchell mentions dips as high as 25 degrees along sections 18 and 13 near the county line in the southwestern part of Wyandot county. The Niagara "here appears as a thick-bedded, gray, and crystalline dolomite." It "rises rapidly.....from below the Water-lime [Greenfield] which lies to the north."

The writer visited this locality on Oct. 9th, 1929, and in company with Mr. Hensel, a life-long resident of the community, saw a number of the outcrops mentioned by Winchell. No dips as high as 25 degrees were seen, however; and neither Mr. Hensel, nor the quarry operators interviewed knew of any such steep dips. On Mr. Hensel's farm a mile southwest of Marseilles, in the extreme northwestern corner of Marion county, the Guelph is exposed in the ditch by

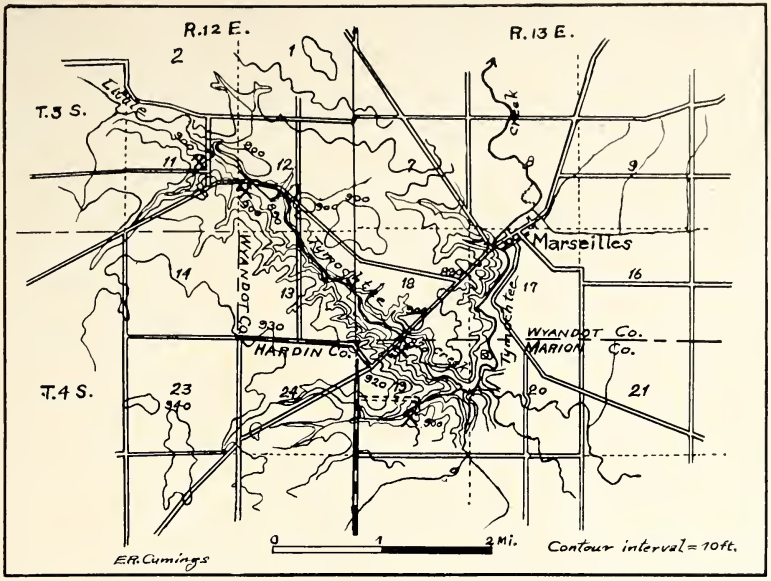

Fig. 2—Map of Marseilles, Ohio, and vicinity, showing location of quarries and outcrops.

the side of the road past Mr. Hensel's house; and in the small gully that leads up the hill from his barn lot, the outcrops running nearly to the top of the hill. The rock along the road is massive and hard, and appears to dip down hill; but the exposure is too limited to permit an accurate determination. At the base of the hill, below Mr. Hensel's house, a small quarry, nearly filled with water, exposes thin bedded Greenfield dolomite. This is 30 to 40 feet lower than the highest outcrops of Niagara. The quarry one and one-half miles southwest of Marseilles, in section 19, T. 4 S., R. 13 E., is in rather even bedded, thin, saccharoidal dolomite of typical Guelph lithology. The Gilland quarry, two miles west of Marseilles, in section 12, exposes the same kind of rock in the main quarry wall; but the floor of the quarry is in very massive, hard, porous, blue dolomite. The dips are slightly irregular, and this quarry may be underlain by reef rock; but the evidence is not clear. The Herzog quarry, near Patterson, 10 miles northwest of Marseilles, shows some arching of the thinner strata near the top of the quarry. The main wall consists of extremely massive, blue, drusy, rough dolomite. This quarry is about 80 feet deep.

It is clear that a ridge of Guelph dolomite rises conspicuously higher in the hills south of Little Tymochtee creek than the outcrops of Greenfield dolomite along the creek. This fact was long ago pointed out by Winchell. In the absence of conspicuous dips, unless those mentioned by Winchell are authentic, it would not be altogether safe to conclude that this is due to reef structures. It is probable that such exist in the locality; but conclusive proof of their presence is not at hand.

The extremely massive character of the Guelph of northwestern Ohio, not only at the localities described above; but at many others, such as Woodville, Genoa, etc., is believed by the writer to be everywhere closely associated with

reef formation. The proven presence of reefs in the Tiffin-Carey area strongly supports this conclusion. Cumings and Shrock (1928) came to the conclusion from their detailed study of the Indiana reefs that in Huntington (Racine-Guelph) time "the reefs.....spread like a Great Barrier Reef over the entire sweep of the shallow waters around the Michigan basin, littering its floor with their pure, calcareous sand, and yielding a congenial habitat to vast swarms of giant brachiopods and massive-shelled molluscs." Clarke and Ruedemann (1903) from general considerations of lithology and faunas and from analogy with known reef formations came to a similar conclusion. On page 121 they say, "In New York the Guelph period was still a time of coral reefs, and the distribution of the peculiar fauna, characteristic of this reef in Ontario and Ohio, shows that probably the entire shallow Guelph basin was more or less studded with coral reefs." And again (p. 135) "Over all this amphitheatre, bounded without by the Niagaran, we may conceive of a shallowing sea, dotted with coral banks which must in no small measure have fringed its shore." So from general considerations these distinguished paleontologists anticipated by a quarter of a century the conclusions now demonstrated by detailed studies such as those of the present paper.

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LISTS OF SPECIES FROM THE NEW CORYDON, KOKOMO AND KENNETH FORMATIONS OF INDIANA, AND FROM REEFS IN THE MISSISSINEWA AND LISTON CREEK FORMATIONS

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1. *The New Corydon dolomite.* In our report on the Silurian rocks of northern Indiana (1928), Dr. Shrock and the writer named and described the New Corydon limestone, from outcrops in Huntington, Adams and Jay counties, Indiana. We also listed a fauna of 13 species—all that had been identified from the formation at that time. These species were mostly well known Lockport corals. The fauna and the lithology of the New Corydon, especially its extremely

cherty character, led us to suppose that the formation represented the final episode of the Niagaran of Indiana.

During the past year two circumstances have thrown considerable additional light on the correlation of the New Corydon. First, the writer has obtained by careful collecting, a considerable list of species in addition to those already known, so that the total is now 33 species. Second, the detailed study of cuttings from two wells in Fort Wayne, drilled by the Fort Wayne water company, has shown that the Huntington formation of northeastern Indiana is 450 feet thick; and that the New Corydon limestone (dolomite) is merely a bed in the middle of the Huntington. These latter facts are reviewed in another paper. At Fort Wayne the New Corydon member is about 100 feet thick.

The species identified from the New Corydon member are as follows, those previously listed being indicated by a star:

Clathrodictyon fastigiatum Nicholson—H.
C. ostiolatum (Nicholson)—H.
Stromatopora antiqua (Nicholson and Murie)—H.
*Cladopora laqueata Rominger—K.
*C. reticulata Hall—K., H.
*C. striata Davis—K.
*Favosites favosus (Goldfuss)—K.
*F. niagarensis Hall—K., S. & B.
F. hisingeri (Edwards and Haime)—H.
F. hispidus Rominger—H.
*Halysites catenularia (Goldfuss)—H., K., S. & B.
*H. labyrinthicus (Goldfuss)—H.
*Strombodes pentagonus Goldfuss—K., H.
*S. striatus (D'Orbigny)—K., H.
Cyathophyllum sp. S. & B.
Alveolites undosus Miller—H.
Alveolites sp.—H.
Lyellia americana Edwards and Haime—H.
Zaphrentis racinensis Whitfield—H.
Syringopora sp. (cf. S. fibrata)—H.
Diphyphyllum sp.—H.
*Conchidium multicostatum (Hall)—H.
*Meristina maria (Hall)—H., K.
*Pentamerus oblongus Sowerby (A small nontypical form)—K. S. & B.
Atrypa reticularis (Linnaeus)—S. & B.
Leptaena rhomboidalis (Wilckens)—K., S. & B.
Whitfieldella sp.—K., S. & B.
Camarotoechia sp.—S. & B.
Coelocaulus bivittatus (Hall)—H.
Liospira perlata (Hall)—H.
Poleumita sp. (A rather large form like P. sp. indt. of Kindle 1904)—H.
Dawsonoceras annulatum (Sowerby)—H.
Odontopleura sp. (A very poor fragment)—H.

H., Huntington; K., J. W. Karsch quarry; S. & B., Smith and Baker quarry.

Clathrodictyon fastigiatum and *C. ostiolatum* are typical Guelph species. So also are *Coelocaulus bivittatus* and *Liospira perlata* and the undetermined species

of *Poleumita*. *Favosites hispidus*, *Halysites labyrinthicus*, *Zaphrentis racinensis* and *Diphyphyllum* favor the Guelph. The others are noncommittal. The species listed as *Strombodes striatus* is probably *S. pentagonus*, which is common at Huntington, and is a well known Racine species. There is nothing in this fauna to indicate that the New Corydon is anything other than a local cherty development of the Huntington; and with the evidence of the Fort Wayne wells this conclusion may be accepted as valid.

2. *The Kokomo limestone.* Prior to the studies of Cumings and Shrock (1928, 1928a) seven species of fossils, mostly Eurypterids, had been reported from unequivocal Kokomo limestone. The collecting of the past year has added 20 species to this meager list. Several of these are new, and will be described and figured in a later paper. Most of the species heretofore reported from the Kokomo are confined to the overlying Kenneth limestone; but several species supposed to be from the Kenneth are restricted to the Kokomo. One of the results of the writer's detailed collecting has been to more clearly differentiate the Kokomo and Kenneth faunas. They are in fact strikingly distinct.

Following is the complete list of the species of the Kokomo limestone. Species previously reported are starred.

Halysites labyrinthicus (Goldfuss)—L.
Cyathophyllum hydraulicum Simpson—L. (Rather larger and of more irregular growth than the typical form).
Cyathophyllum sp. (Possibly an Amplexus)—L.
Stromatoporoid (Not generically identifiable)—L.
Conchidium n. sp. (Near C. nysius)—L.
Conchidium n. sp.—L.
Conchidium sp. (cf. C. laqueatum)—L.
*Pentamerus divergens Foerste—K. L.
Pentamerus sp.—L.
*Spirifer corallinensis (Grabau)—L.
Schuchertella interstriata (Hall)—L.
Atrypa reticularis (Linnaeus)—L.
Reticularia n. sp.—L.
Dalmanella parva n. sp.—L.
Dalmanella n. sp. (A larger form)—L.
Leperditia ohioensis Bassler L.
Leperditia sp. (Smaller and probably distinct)—L.
Conocardium sp.—L.
Buthotrephis sp.—L.
A Ceratiocarid—L.
*Anomalocaris (?) kokomoensis Ruedemann—K.
*Buthotrephis divaricata David White—K.
*B. newlini D. White—K.
*Eurypterus (Onychopterus) kokomoensis Miller and Gurley—K.
*E. ranilarva Clarke and Ruedemann—K.
*Eusarcus newlini (Claypole)—K.
*Stylonurus (Drepanopterus) longicaudatus Clarke and Ruedemann—K.

L., Logansport; K., Kokomo.

This is an extremely interesting fauna, and completely confirms the long suspected correlation of the Kokomo limestone with the Bertie-Akron of New

York and Ontario. The presence of *Cyathophyllum hydraulicum* and *Schuchertella interstriata* is especially significant These come from a rather massive brown dolomite in the upper half of the formation at the quarry east of Logansport. The long, contorted, slender coralla of the *Cyathophyllum* are exceedingly abundant at this locality. *Leperditia* (the smaller form for the most part) is also very abundant east of Logansport; but the typical *ohioensis* occurs very commonly about midway of the formation at the abandoned Blue Hole quarry west of Logansport. The specimens are very perfect and of large size. No bioherms of stromatoporoids, such as characterize the equivalent Greenfield dolomite in Ohio, have been found in the Indiana region. Across the Wabash river from the County Club, east of Logansport, however, a beautiful bioherm of *Halysites* is exposed in the river bank. The coral fills the rock.

The term *bioherm*, recently proposed by Cumings and Shrock (1928a), is here preferred to the much abused term reef; and is defined as consisting of *any dome-like, mound-like, lense-like or otherwise circumscribed mass, built exclusively or mainly by sedentary organisms such as corals, stromatoporoids, algae, brachiopods, molluscs, crinoids etc., and enclosed in normal rock of different lithologic character.* The word comes from two Greek words meaning *organic*, and *reef* or *mound*.

3. *The Kenneth limestone.* Cumings and Shrock (1928) listed 21 species from the Kenneth limestone of Indiana. The present writer finds that three of these, *Pentamerus divergens, P. pesovis* (probably) and *Spirifer corallinensis*, are confined to the Kokomo limestone. *Spirifer exiguus* has not been found by the writer in either the Kokomo or the Kenneth limestones. It may quite certainly be excluded from the Kenneth. The collecting of the past year has added several interesting species to the list.

Below is a complete list of the species of the Kenneth limestone:

Amplexus septatus Foerste—K., L.
Cladopora sp.—L.
Favosites pyriformis kokomoensis Foerste—K.
Favosites sp.—L.
Cyathophyllum sp.—L. (A slender cylindrical form).
Halysites catenularia (Linnaeus)—K., L.
Chonetes colliculus Foerste—K., L.
Chonetes sp.—K., P.
Conchidium colletti (Miller)—K., L.
Coelospira congregata (Kindle and Breger)—K., L.
Dalmanella elegantula (Dalman)—K., L. (This is a small species, and probably is distinct from D. elegantula).
Dalmanella n. sp.—L. (A small form with high carinate ventral valve like D. postelegantula of the Decker Ferry formation).
Gypidula n. sp. (A smooth form very much like Weller's Pentamerus circularis, which is probably a Gypidula; and like the Keyser Gypidulas)—L., K.
Gypidula n. sp. (Small plicated form)—L., K.
Leptaena rhomboidalis (Wilckens)—L., K. (Small, with few rugae).
Atrypa calvini Nettleroth (var.)—K.
Uncinulus stricklandi var.—K.
Rhynchospira cf. globosa (Hall)—K.

Rhynchotreta cuneata (Hall)—K. (A poorly preserved speciemen doubtfully referred to this species).
Strophonella sp.—K.
Scenidium n. sp.—L. (Plications as in the Lower Helderberg species).
Whitfieldella erecta Foerste—K. (May be a Hindella).
Hindella sp.—L. (A very minute species similar to H. congregata of the Keyser).
Wilsonia kokomoensis (Miller)—K., L.
Isochilina musculosa Foerste—K.
Kloedenia kokomoensis Foerste—K.
Dizygopleura cf. clarkei paupera Ulrich and Bassler (Very close to that species)—L.
Orthoceras sp.—K.
Cystid plate, very close to Pseudocrinites gordoni Schuchert.

L., Logansport; K., Kokomo; P., Pipe Creek Falls.

The fauna of the Kenneth is intensely interesting. It is unlike anything else in the Michigan Basin region; but very suggestive of the Decker Ferry-Keyser fauna of New Jersey, Pennsylvania and Maryland. *Coelospira congregata*, which is the commonest species, and is often extremely abundant, is nearly identical with *C. concava tonolowayensis* Swartz of the Keyser. The next most abundant species, *Gypidula* n. sp. (Smooth form), is very similar to the Keyser Gypidulas and to *Pentamerus circularis* Weller, which is probably a *Gypidula*, from the Decker Ferry formation. The small carinate *Dalmanella* from the Kenneth is close to the Dalmanellas of the Keyser. Foerste's *Favosites pyriformis kokomoensis* is nother species of suggestive relations. His *Whitfieldella erecta* may very likely be a *Hindella;* but in the absence of the internal structure this point cannot be settled. A very minute *Hindella* quite certainly occurs in the Kenneth. *Rhynchospira globosa*, though somewhat doubtfully identified, is another Keyser form. *Chonetes colliculus* may be closely related to *C. jerseyensis* of the Keyser. It is very abundant in the Kenneth. The cystid plate and the little *Dizygopleura* are significant. If these species indicate the correlation of the Kenneth limestone of Indiana with the Keyser and Decker Ferry formations, it would be interesting to know by what route they migrated between the two widely separated localities. There is no correlative of the Kenneth in the Monroan of Michigan, nor so far as known, in the rocks of Ohio.

4. *Liston Creek reef at Lapel.* At the time of the publication of the Silurian rocks of Northern Indiana (Cumings and Shrock, 1928) no exhaustive collections had been made from unequivocal Liston Creek and Mississinewa reefs, and especially from the latter. The opening of a quarry and drainage ditch in an extensive reef flank north of Lapel, Indiana, and the belated discovery of an excavation in the flank of a Mississinewa reef along the drainage canal in section 20, T. 27 N., R. 4 E., northwest of Peru, Indiana, furnished an opportunity to make such collections. Several species of great value in correlation are included in these collections.

The fauna of the Liston Creek reef north of Lapel is as follows:

Amplexus sp.
Alveolites louisvillensis Davis.
Alveolites sp.
Cladopora n. sp. (Very slender stems and few rows of corallites).

Cladopora sp.
Cyathophyllum cf. radicula Rominger
Favosites favosus (Goldfuss).
F. hisingeri (Edwards and Haime).
F. niagarensis Hall.
Halysites catenularia (Linnaeus).
H. labyrinthicus (Goldfuss).
Heliolites elegans Hall.
Pycnostylus elegans Whiteaves (?)
Thecia minor Rominger.
Zaphrentis stokesi Edwards and Haime.
Zaphrentis sp. (Slender with very irregular growth).
Receptaculites sp. (Coarser structure than R. hemisphericus).
Clathrodictyon sp.
Stromatopora antiqua (Nicholson and Murie).
Pisocrinus sp.
Two other species of crinoids, not identifiable.
Atrypa calvini Nettleroth.
A. reticularis (Linnaeus).
Camarotoechia sp.
Conchidium laqueatum (Conrad).
C. littoni (Hall).
C. multicostatum (Hall).
C. nysius (Hall and Whitfield).
Cyrtia myrtia (Billings).
Dalmanella elegantula (Dalman).
Leptaena rhomboidalis (Wilckens).
Meristina maria (Hall) (Very large individuals).
Pentamerus sp.
Orthis flabellites Foerste (As figured by Kindle. Probably a distinct species).
Reticularia bicostata petila (Hall).
Spirifer foggi Nettleroth.
S. nobilis (Barrande).
S. crispus (Hisinger).
Strophonella semifasciata (Hall).
Stricklandinia sp.
Schuchertella subplana (Conrad).
Whitfieldella nitida (Hall).
W. cf. marylandica Prouty.
Fenestella sp.
Poleumita sp.
Actinoceras sp. (Siphuncle).
Kionoceras cancellatum (Hall).
Kionoceras sp. (Longitudinally ribbed like K. angulatum as figured by Grabau, Index Fossils).
Bumastus ioxus (Hall).
Calymene niagarensis Hall.
Calymene cf. vogdesi Foerste.
Encrinurus indianensis Kindle and Breger.
Illaenus sp. (cf. insignis).

Of these species, *Alveolites louisvillensis, Cyathophyllum radicula, Zaphrentis stokesi, Conchidium littoni, C. nysius, Reticularia bicostata petila, Strophonella semifasciata, Whitfieldella* cf. *marylandica, Actinoceras* sp., and *Kionoceras* aff. *angulatum* are new additions to the Liston Creek fauna. *Thecia minor* has not heretofore been found in reef rock. Several of the above species are especially indicative of the correlation of the Liston Creek formation with the Louisville formation. Such are, *Alveolites louisvillensis, Zaphrentis stokesi, Conchidium littoni,* and *C. nysius.* To the numerous Louisville species already known from the Liston Creek formation may also be added *Romingeria vannula* Davis, recently collected from typical Liston Creek cherty limestone at Huntington, and *Lyellia americana* from the Liston Creek reef at Markle. The single specimen of *R. vannula* is beautifully preserved and absolutely typical. The correlation of the Liston Creek limestone with the Louisville can, therefore, no longer be regarded as doubtful.

5. *Mississinewa reef northwest of Peru.* After most of our 1928 paper was in manuscript, Dr. Shrock discovered an isolated excavation through the flank of a reef in the Mississinewa shale, along the drainage canal through the level valley land in section 20, northwest of Peru. The outcrop is briefly described on page 159 of our report (1928). The canal at this point cuts through the flank of a reef, and large piles of the reef rock have been thrown out on either side of the canal just east of a farm bridge across the canal. For some distance east along the canal the excavation is in typical Mississinewa shale. Four hundred feet west of this outcrop the canal is excavated through typical Kokomo limestone, much contorted and brecciated. It appears likely that the extreme brecciation and contortion of certain layers in the Kokomo may be due to submarine solifluction on the slopes of these buried Mississinewa reefs. Low klintar rise a few feet above the valley floor, both to the north and south of the drainage ditch. Dr. Shrock has found several other small outcrops of reef rock in the level valley land west of Peru. These prick through the Kokomo limestone which outcrops at several points in the valley. (See Cumings and Shrock, 1928, pp. 128-129 and 159-160). Evidently a very large number of reefs lie buried beneath the Kokomo limestone of Indiana.

The fauna of this reef flank in the drainage canal is as follows:

Fenestella cf. elegans Hall.
Fenestella sp.
Fistulipora neglecta maculata Hall (?)
Chilotrypa ostiolata (Hall).
Polypora cf. punctostriata (Hall).
Polypora sp.
Pseudohornera niagarensis (Hall).
Semicoscinium sp. (Near acmeum).
Spatiopora maculata (Hall).
Trematopora sp.
Pinnatopora sp.
Atrypa reticularis (Linnaeus).
Anastrophia internascens Hall.
Camarotoechia indianensis (Hall).
C. neglecta (Hall).
C. whitei (Hall).

Leptaena rhomboidalis (Wilckens).
Spirifer crispus (Hisinger).
S. crispus simplex (Hall).
Schuchertella subplana (Conrad).
Stropheodonta sp.
Strophonella semifasciata (Hall).
Pentamerus n. sp.
Trematospira cf. camura Hall.
Strophonella striata (Hall).
Rhipidomella hybrida (Sowerby).
Whitfieldella nitida (Hall).
Wilsonia n. sp. (Near W. saffordi, but more nearly spherical).
Pterinea emacerata (Conrad).
Leiopeteria subplana (Hall).
Dawsonoceras annulatum (Sowerby) (Longitudinal ribs like D. granti Foerste).
D. americanum (Foord).
Discoceras cf. marshi (Hall) (Annulations rather closer and less oblique).
Kionoceras cancellatum (Hall).
Encrinurus indianensis Kindle and Breger.
Bumastus ioxus (Hall).
Illaenus sp.
Pisocrinus campana Miller (Arms of calyx).
Crinoid sp.

The fossils of this reef rock, which is strongly dolomitized and very porous, are mostly very poorly preserved. This applies especially to the Bryozoa, which are extremely abundant. The zooecia of the Fenestellids were not clearly seen in any specimen, so that identifications are based on the general appearance and proportions of the very numerous zoaria. Among the brachiopods *Leptaena rhomboidalis* is far and away the most abundant, being extremely common. The two pelecypods are identified with some hesitation; but are at least very close to the species indicated. The presence of *Pisocrinus*, heretofore reported only from the Liston Creek limestone in northern Indiana, is very interesting, and indicates along with much other evidence that that genus and its associates belong in very early Lockport and pre-Lockport. The general cast of this fauna is Rochester; and is in line with the indications of the extensive graptolite fauna described by Shrock (1928). It is interesting that this reef is mainly composed of bryozoan remains.

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INTRAFORMATIONAL SOLUTION OF THE FLOYDS KNOB LIMESTONE

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Introduction. Further significance of intraformational dissolving of rocks has been revealed from numerous observations made incidental to the study of the stratigraphy of the Floyds Knob formation of the Borden (Knobstone) group of southern Indiana. Previous studies of the writer[1] have already developed various stratigraphic peculiarities, in limestones particularly, which cannot be ascribed to events at the time of the birth of the rock but which are explained by partial dissolving of the rock subsequent to the deposition and consolidation of the sediments. The *complete* removal in places of the soluble constituents throughout the entire thickness of the limestone facies, with a bed of reddish-brown claylike residuum offering the only testimony to the original existence of the limestone layer, is the unique feature of the Floyds Knob formation which provokes the offering of this paper.

Floyds Knob Formation. Extensive field study of the Borden rocks throughout the unglaciated area of southern Indiana, and incidental observation in adjacent parts of Kentucky, revealed a persistent unit in the upper part of the Borden group which has served as a vital key to subdividing the rocks and to properly associating the uppermost Borden formations with the overlying Harrodsburg and Salem limestones. The name Floyds Knob formation is being suggested for this unit[2]. This formation is one exhibiting several lithologic facies, the most common of which is a limestone that is itself of differing traits from place to place. For this limestone phase the name Goss Mill limestone facies is being suggested.

The thickness of the Floyds Knob formation, the Goss Mill facies, is commonly 3 to 4 feet. In but a few places it is as much as 8 feet or more. The facies crops out in southeast Harrison County; south, east-central, and northeast Floyd County; parts of extreme west Clark County; southwest Scott County; southeast, north, and northwest Washington County; southeast, east and a limited part of northeast Lawrence County; southwest, west-central and northwest Jackson County.

In some places the Goss Mill facies is a ferruginous, siliceous, brittle limestone, carrying a deep-brown color at weathered exposures. The following analysis of a sample from the exposure along State Highway No. 62, at the northwest corner sec. 6, T. 3 S., R. 6 E., about one-fourth of a mile northeast of the village of Edwardsville, illustrates the composition:

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[1]Stockdale, Paris B., Stylolites: their nature and origin: Indiana Univ. Studies, Vol. 9; No. 55 1-97, 1922; The stratigraphic significance of solution in rocks: Jour. Geology, Vol. 34, 399-414, 1926.

[2]Complete results of the writer's stratigraphic studies of the Borden group have been prepared in a report for publication by the Indiana Department of Conservation, Division of Geology. In this, the stratigraphic subdivision of the Borden rocks and appropriate names for the several stratigraphic units and their facies are being proposed.

	Per cent
Silica (SiO_2)	42.80
Alumina (Al_2O_3)	1.80
Ferric oxide (Fe_2O_3)	6.40
Calcium carbonate ($CaCO_3$)	46.70
Magnesium carbonate ($MgCO_3$)	2.05
Total	99.75[3]

A much higher magnesian content is indicated by the following analysis of a sample from near the top of the quarry of the Lehigh Portland Cement Company, SE. ¼ NE. ¼ sec. 18, T. 4 N., R. 3 E., one mile east of Sparksville:

	Per cent
Silica (SiO_2)	18.84
Alumina (Al_2O_3)	3.99
Ferric oxide (Fe_2O_3)	9.25
Calcium carbonate ($CaCO_3$)	43.65
Magnesium carbonate ($MgCO_3$)	22.79
Total	98.52[4]

At numerous places the formation is a fairly pure limestone, being crinoidal, oolitic or crystalline, or most commonly a combination. The color of such a limestone where fresh ranges from light to dark gray. Numerous small brown specks are common to the stone. Vertical and lateral transitions from the more pure to the impure, ferruginous, siliceous stone are frequent. North of Lawrence County the Floyds Knob formation is of a facies characterized by little limestone but dominated by a peculiar, brittle, yellowish siliceous rock, only slightly calcareous.

Various Indiana workers have referred to the different limestone facies of the Floyds Knob formation as the "Stevens Creek Limestone", although the name has never been formally proposed in the literature. Preëmption of the term for the "Stevens Creek slates"[5] of south Carolina, and confusion in the interpretation of different beds which have been referred to the same horizon in the northern part of the unglaciated outcrop area, preclude continuation of the name "Stevens Creek." The foregoing description of the Floyds Knob formation is intentionally a meager one. Complete discussion of the formation and its many complex problems and confusing stratigraphic associations are given lenghty treatment in the previously mentioned report which deals with the stratigraphy of the entire Borden group.

REVIEW OF THE INTRAFORMATIONAL SOLUTION PROCESS

The strongly supported fact that solution by ground waters within a rock mass is the vital factor in the development of stylolites, brought to the writer's attention the question of how significant has been *intraformational solution* in

[3]Analysis by Paul Smith.
[4]Furnished by W. H. Weitknecht.
[5]Sloan, Earl, Catalogue of mineral localities: South Carolina Geol. Survey, 1908.

producing other effects which require consideration in the interpretation of geologic sections and in the making of historical deductions. Before treating the observations in the Floyds Knob formation, Goss Mill limestone facies, which have further bearing on the subject, pertinent points relevant to the nature o- intraformational solution will be reviewed.

Significance of Stylolites. Stylolites present a peculiar and unique phenomenon which has been observed by all. Their manner of origin is relatively simple. Chemical and field investigations have strongly confirmed the idea that stylolitic phenomena are developed in certain types of rocks by *differential* chemical solution of the *hardened* strata, rather than developed in the soft unconsolidated sediments at the time of, or shortly following deposition, by some peculiar differential compression[6]. Stylolites, thus, are one case of a secondary stratigraphic feature, produced by a secondary process—solution—in the already hardened strata. Inasmuch as comparatively little attention has been given to this type of solution work, certain geologic significances of it have been largely overlooked. In addition to having produced, under proper conditions, the peculiar stylolitic and related phenomena in rocks, the stratigraphic importance of the solution is primarily twofold:

1. A part of the original rock has been removed and the beds consequently have been made thinner. Thus the apparently complete record of sedimentation is not represented in a given bed, and various peculiar relationships may have resulted.

2. Thin claylike films or partings have been developed within and between the beds as a residual product of the dissolved rock. Such partings are not original sedimentary layers, but have been introduced into the rocks as partings subsequent to the deposition of the sediment, and require a unique interpretation.

Prominent solution is restricted to carbonate rocks—principally to limestones, dolomites, and marbles. Stylolites are, with rare exceptions, limited to such types of rocks. They are not to be found in clastic rocks (except, perhaps, in occasional horizons where a high carbonate content is present), in igneous rocks, nor in most types of metamorphic rocks. Although solution is slightly effective upon materials which are nearly insoluble, such as quartz—especially when long periods of time such as geology offers are available—the effect is little as compared with that in the much less resistant rocks. The frequency of stylolites in limestones and marbles is, of course, well known.

Stylolitic phenomena result from a *differential solution* of the consolidated rock, under some pressure, on the two sides of a parting, such as a bedding plane, the undissolved portions of the rock on the one side fitting into the dissolved parts opposite, the interfitting taking place slowly and gradually as solution continues. A normal claylike substance is left as a residue from the dissolved rock. Most of this residue rests as a cap at the ends of the stylolites. The sides of the columns are fluted, striated, and even slickensided as a result of the slow movement involved.

Essential factors in the development of stylolites may be summarized as follows: (1) A first requisite is a rock which is differentially soluble. Most commonly limestones, dolomites, and even marbles are not uniformly resistant throughout. Evidence of differential resistance to solution of such rocks is strikingly presented in honeycombed weathering effects. (2) Ground waters,

[6]Stockdale, Paris B. *Ibid.*

charged with carbon dioxide, must be present to act as the dissolving agent in producing stylolites. (3) Some sort of parting, along which water circulation is free and concentrated, is needed. This parting is most commonly a bedding plane, though it may be a crevice running in any direction—even a fault. It may be an unconformity. No original clay layer is necessary along the parting. (4) Pressure is needed to make stylolites. It may be static, resulting from the weight of the overlying rocks, or it may be lateral dynamic pressure. The amount of pressure need not be great. (5) Sufficient amount of time must be allowed. Since variations of the foregoing factors occur, solution produces effects with a great many differences.

No attempt will be made here to discuss the variations in the types of stylolites nor to review the abundance of evidence substantiating the theory that stylolitic features originate in hardened rock by solution and removal of material, instead of in soft plastic sediment by differential compression before consolidation. The prevalence of stylolites, originating in such a manner, indicates that solution is important in the modification of strata.

Reduction in Thickness of the Strata. Inasmuch as solution work of the type involved in the origin of stylolites leaves no cavities, the strata are necessarily reduced in volume in proportion to the amount of material that has been dissolved and carried away. That rock material has been actually removed from beds and that a part of the record of sedimentation has thus been lost, and that a new type of rock material, a residuum, has been introduced into the beds are significant factors commonly overlooked by geologists. Such changes are strikingly true in the case of the Floyds Knob limestone. Calculations have shown an approximate minimum loss from intraformational dissolving of as much as 35 per cent in some of the highly stylolitic beds of Tennessee marble (Holston formation). This figure is based upon the composite length of stylolites in the numerous stylolite-seams, compared with the total thickness of the beds. Where dissolving has not been differential, stylolites are absent, and a solution parting of fair regularity with its film or bed of residuum offers testimony of rock removal. Excessive dissolving along a restricted line initiates a cavern.

Intraformational Residuum. No limstone, dolomite, or marble is composed of 100 per cent carbonates capable of being removed through the action of waters charged with carbon dioxide. Decomposition of such rocks by solutions leaves a claylike residue consisting of the less soluble constituents most of which are nothing more than the clastic silts which had drifted out into the limestone making waters. The amount of residue which accumulates is dependent upon two main factors; namely, (a) the proportion of insoluble constituents in the original rock, and (b) the amount of rock which has been decomposed. The nature of such weathering is well known and will not be reviewed here. It has been common practice to interpret all types of thin claylike partings in limestones, dolomites, and marbles as signifying simply a temporary change in conditions of sedimentation from those requisite for limestone-making to those necessary for clastic silt accumulation. This erroneous view has often been accepted in connection with the caps of stylolites, in which case an original, continuous silt layer is considered as having been broken by the interpenetration of the columns.

The solution residue is not a true clay, or kaolin, for the chemical alterations necessary to convert a clastic silt sediment to kaolin are not completed in the initial decomposition of limestone. This would be especially true where the

solution is within the beds and the minerals are not freely exposed to atmospheric gases. The residue is merely a concentration, with little chemical alteration, of the clastic fragments scattered throughout the limestone. Thus, chemically, such residual "clays" vary little from the expected composition of an ordinary shale. They may be very sandy. Such residual partings, however, lack the lamination produced by the sorting action of open waters.

SOLUTION EFFECTS IN THE FLOYDS KNOB LIMESTONE

The following are the important effects which dissolving has produced or helped to produce in the limestone phases of the Floyds Knob formation: (a) the outcrop where long exposed to weathering has become an incoherent, reddish-brown sandy clay; (b) there has been a meager development of stylolites; (c) small caverns, partly or completely filled with reddish-brown residuum, have been made at numerous places; (d) a total, or nearly total removal of the limestone, with a bed of residuum left in its stead, has resulted in some places; (e) minature faulting of overlying sandstone beds has been produced as a consequence of settling necessitated by removal of the limestone beneath.

At many outcrops, particularly of the more impure limestone facies of the Floyds Knob formation, aerial and sub-aerial dissolving, accompanied by other processes of weathering, have converted the limestone into rock ranging from but slightly modified, fairly resistant stone with a reddish-brown weathered surface, to a soft, incoherent, sandy reddish to yellowish-brown residuum. Quarrying back from the exposure has revealed the fresh rock. Where a high degree of decomposition of the stone has taken place at the outcrop one can readily overlook the presence of the formation, particularly if the overlying and underlying siltstones are badly disintegrated. Such situations have caused field workers to miss the formation at places where it is present and where knowledge of its existence would serve as a valuable factor in making stratigraphic and structural computations. This type of weathering is, however, of less concern in this treatment than that which has gone on underground, probably beneath the water table, and has not been governed by aerial exposure.

Stylolites are rare, though present in a few places where the rock is fairly pure. The Floyds Knob formation is a thin one and is commonly a single bed which does not offer a satisfactory parting within the zone along which dissolving would occur on opposite sides both above and below. Nevertheless, the existence of stylolite-seams in some of the bedded zones, as at the type section along U. S. Highway No. 150, center sec. 21, T. 2 S., R. 6 E., about one mile east of Floyds Knobs Post Office, gives testimony of the previously described type of differential intraformational dissolving.

The many small caverns which exist are unusual in a formation as thin as the Floyds Knob. (See Figs. 1 and 2.) The presence of an underlying tight formation of siltstone which offers resistance to the downward percolation of waters gives occasion for lateral circulation of ground waters at the horizon of the limestone facies of the formation. Springs and seepage are an expression of the situation. At some places the formation is so very cavernous that a greater portion of the stone is missing, and only remaining pillars serve as support for the overlying strata. The caverns contain large quantities of the residuum. Examination of the foregoing analysis of the limestone reveals high proportions of insoluble constituents which would be left as a concentrate from decomposition of the formation.

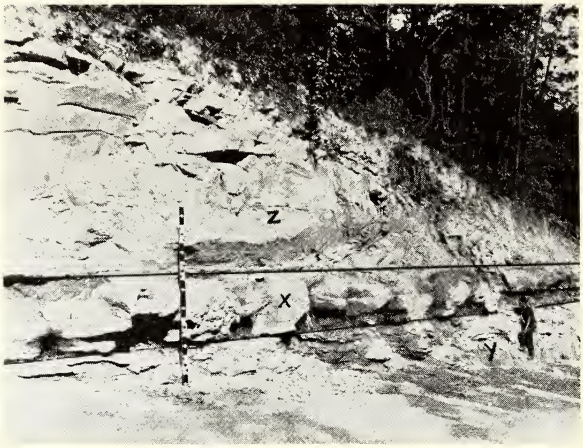

Fig. 1—Exposure along State Highway No. 62, near the northwest corner sec. 6, T. 3 S., R. 6 E., a short distance northeast of the village of Edwardsville. The Floyds Knob formation (X) here is 4 feet thick, consisting of a lower 2-foot zone of variable limestone, transitional with an overlying 2-foot bed of calcareous sandstone. The small caverns, partially filled with residuum, are testimony of the dissolving of the limestone. At the extreme right (man's hand) no limestone exists; in its stead there is a one-foot layer of reddish-brown residual clay.

Fig. 2—Exposure on the north side of U. S. Highway No. 150, at the top of Floyds Knob hill, center sec. 21, T. 2 S., R. 6 E., about one mile east of Floyds Knobs Post Office, showing the effects of intraformational solution in the Floyds Knob limestone. At the left end of the exposure there is no limestone; in its stead is a 3-foot layer of reddish-brown residuum (R). The overlying sandstone bed (Z) has been faulted down (at man's hand) due to total removal of the limestone beneath. To the right of this photograph the limestone is 5 feet thick. A cavern is hown at C. The man is standing upon a remnant of the limestone at the base of the formation.

Complete Destruction of the Limestone. In the making of stylolites no open cavities are left in the rock and the beds on opposite sides of the "solution parting" are uniquely interdovetailed as differential dissolving takes place. Partial loss of the rock and a reduction of thickness result. However, if widespread dissolving goes on more or less evenly in a bed on one side of a parting, or is shared by the layers on both sides, a stylolite-seam would not be produced. Thinning of the rock would be evidenced only the existence of the layer of

residuum. Caverns, of course, are initiated through dissolving along restricted lines.

In the Floyds Knob formation there are places where the limestone throughout its entire thickness has been leached of its soluble carbonates. In the place of the limestone there is left a residual bed. (See Fig. 1.) It is this residuum that has been misinterpreted by some field observers. Relation of this layer of residuum to the previously existing limestone must be appreciated by workers in the area, otherwise a valuable key to the study of the straitgraphy and structure is overlooked. To interpret this bed as a clastic deposit signifying merely a temporary change in conditions of sedimentation, as a peculiar facies of rock whose lateral associations are unimportant, is fallacious. Prior to recent excavations a one-foot outcrop of reddish-brown clay was the feature of a significant section along State Highway No. 62, at the northwest corner sec. 6, T. 3 S., R. 6 E., about one-fourth of a mile northeast of the village of Edwardsville. In this "clay" are corroded chunks of the Floyds Knob limestone. The relation of this residual layer to the limestone was unappreciated by Butts, for example, who simply gave in his Edwardsville section one foot of "red clay"[7]. Butts listed the 2 feet of stout siltstone which overlies the "red clay" as the topmost bed of the "Holtsclaw sandstone". In the Kentucky sections a thin "layer of oolite", present at places, had been regarded as marking the top of the "Holtsclaw sandstone" and as occupying a position at the "base of the Warsaw". This thin "layer of oolite" is the Floyds Knob limestone. Since at Edwardsville the limestone was missing in the section, but in its stead there was the unappreciated red claylike residuum, proper correlation and interpretation were overlooked.

Recent quarrying incident to widening of the highway has revealed much more of the Floyds Knob formation at the above discussed location near Edwardsville. (See Fig. 1.) Unaltered and cavernous limestone has been brought to view. The limestone layer is as much as 26 inches thick, the upper part being quite impure, siliceous, and transtitional into a stout calcareous layer of sandstone. At the end of the exposure where the limestone has been decomposed, the claylike layer has a thickness of some 10 inches. This at first appears to be an excessive quantity of residuum from so thin a limestone bed, but examination of the foregoing analysis of the limestone will reveal adequate insoluble constituents.

There are numerous other locations at which the Floyds Knob formation on first observation might be declared "missing", but careful examination will reveal a bed of residuum offering definite testimony to the horizon of the formation. Again, it is to be admitted that at a few places no positive evidence of the formation's existence is available. Along the road leading north from the top of Mitchell Hill, Jefferson County, Kentucky, there is a 12-foot exposure of massive, oolitic, crinoidal limestone, the Floyds Knob. Less than one-fourth of a mile away, along the road leading south from the top of Mitchell Hill, the limestone is absent. At its horizon, however, is one foot of greenish (glauconitic) clay, overlain by a thin zone of reddish-brown residuum. The inference is that originally a limestone representative was there present, although it was not necessarily nearly as thick as the exposure a short distance to the north. Numerous other similar examples could be cited.

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[7]Butts, Charles, Geology and mineral resources of Jefferson County, Kentucky: Kentucky Geol. Survey, ser. 4, vol. 3, pt. 2, pl. 53, opp. p. 158, 1915: Description and correlation of the Mississippian formations of western Kentucky: Kentucky Geol. Survey, pl. 6, opp. p. 28, 1918.

Faulting. One of the singular effects of the removal through intraformational dissolving of the Floyds Knob limestone has been faulting of the overlying sandstone beds at a few places. Recent excavations along the north side of U. S. Highway No. 150, center sec. 21, T. 2 S., R. 6 E., about one mile east of Floyds Knobs Post Office, have revealed the situation illustrated in Fig. 2. The original limestone bed was 5 feet thick. At the west end of the exposure there is no limestone at the outcrop, but instead there is a 2 to 3-foot bed of reddish claylike residuum. The 2-foot basal sandstone bed of the overlying Edwardsville formation has been faulted down into the clay bed where the original limestone support has been removed. The throw of this small fault is 2 feet.

Conclusion. The significant effect of intraformational dissolving in the limestone facies of the Floyds Knob formation of southern Indiana has been the total removal at numerous places of the soluble constituents of the rock, with a bed of residual material left in its place as an indicator of the horizon of the formation. Such residual beds have been falsely interpreted in the past as layers of clastic sediment, and as a consequence their horizon has been misinterpreted and their association with the Floyds Knob formation have not been understood. Stylolite-seams, small caverns, and minature faults are other features which owe their genesis to solution within the formation.

NOTES ON SOME NORTHWESTERN INDIANA ROCK EXPOSURES

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and
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Introduction. It is the purpose of this brief paper to present some of the results of an investigation of a number of rock exposures in northwestern Indiana. Some of these exposures have been described previously by various investigators, but others have not. The investigation was carried on during the field season of 1929.

The exposures here discussed occur in an area comprising parts of Newton, Jasper and White counties. The area lies in the flat Wisconsin drift plain where rock exposures are rare and surprisingly present. The exposures are usually very small and occur in local quarries or in shallow stream beds widely separated and hemmed in by the mantling drift. Many of the quarry openings have long been abandoned and the exposures are so obscured that they do little more than barely suggest the character of the rock. Some of the quarry and stream expsoures, however, are very good, although their limited size and wide separation often make correlations insecure and doubtful. The accompanying map (Figure 1) represents an attempt to depict the general subglacial geology of the area, and is based on the exposures studied, the information indicated by certain well records, and the general relations which the region bears to the larger structural conditions of this part of northern Indiana. It is to be noted that the identification and distribution of the formations depart considerably from the geological maps which have been published in the past.

Kentland Exposures. The three quarries located about three miles east of Kentland in southern Newton County, Section 25, T. 27 N., R. 9 W., reveal parts of the most complicated structure in Indiana. The present active quarry is quite large, occupying several acres, and the rock now being taken from the bottom of the quarry is 60 feet below the surface. The strata are inclined at high angles, in some places closely approaching verticality, and the strike of the upturned layers is far from uniform especially in the south half of the quarry. The other two quarries of the group have been abandoned for a long time. One of them lies about 300 yards southeast of the large active quarry, while the other lies about 600 yards west. These two quarries are rather shallow, but they clearly reveal the upturned strata which are very similar to those of the main quarry. The structure in these quarries has resulted from intense deformation by both folding and faulting. Rocks are exposed here which in nearby localities, in some cases less than three miles, are 1,500 feet beneath the surface. Such structure, occurring as it does in a region of flat-lying rock remote from known areas of intense deformation, is very surprising, and, of course, intensely interesting to the geologist. A paper giving the details of this area is being prepared, and in it will be presented the evidence for conclusions stated below.

*Contributions from the Waterman Foundation, No. 45.

The rocks in the Kentland quarries were first referred to the Niagaran, and the attitude of the strata referred to the same cause as that for the so-called "domes" along the Wabash River.[1] It has been shown, however, that these so-called "domes" are ancient coral reefs of Niagaran age (Cummings and Shrock, 1927, 1928), and that the strata at Kentland are of Ordovician age (Collett, 1883, 58-59; Greene, 1906, 11-17 and Foerste, 1921, 278). The structural situation at Kentland is apparently in no way related to the reefs.

Although Collett (1883, 58-59) was the first to actually assign these rocks to the Ordovician, much of the credit belongs to G. K. Greene, for it was he who collected and identified the fossils which formed the basis for Collett's statement. Greene (1906, 11-17), himself, nearly twenty-five years later revived the idea of the Ordovician age of the rocks. During this interval they had been almost universally referred to the Niagaran. Foerste (1921, 278) recently listed a number of additional species, and stated that they occurred "in a very fine-grained, brownish-gray limestone having a conchoidal fracture, resembling some phases of the Plattin limestone of eastern Missouri." He referred the rocks to the Black River, and thereby corroborated the earlier correlation of Greene, who referred his species to the Lower Silurian (Ordovician).

Mr. Shrock has already identified 14 species, in addition to those listed by Greene and Foerste, from the westernmost of the three quarries, and all are typical forms in the Black River-Trenton series of Minnesota. The strata in the two abandoned quarries have been found to be the same. It is almost certain that they represent rocks of Black River-Trenton age, and it is also very likely that rocks of the same age occur in the larger active quarry.

Quarry 5 Miles South of Wolcott. In the extreme southwestern corner of section 19, T. 26 N., R. 5 W., the White County Stone Company is operating a small quarry in a limestone of Devonian age. The following section was measured in the quarry:

6.	Light pink to gray, thin-bedded, coarsely crystalline limestone	6′
5.	Blue to gray sandy shale	1½′
4.	Thin-bedded gray limestone	1′
3.	Blue to gray sandy shale	1½′
2.	Thin-bedded, gray crystalline limestone with occasional chert nodules	5′
1.	Light gray crystalline limestone with some chert	1½′
	Total	16½′

Several feet of soil overlie the limestone. The slabby, coarsely-crystalline character of the rock, along with the presence of a large brachiopod, *Spirifer* cf. *divaricatus* and several corals, indicate that it is of Devonian age. It very probably correlates with the Onondaga (Jeffersonville) of the Wabash valley. On the geological map of Indiana published by Blatchley in 1904 the New Albany shale is mapped as the subglacial formation where the quarry is located. This exposure of Devonian limestone occurs nearly 15 miles west of the main mass of limestone to which it belongs.

The occurrence of Devonian limestone here is rather unexpected, and its presence indicates an interesting structural irregularity of probable anticlinal

[1]For a discussion of the literature see Cumings and Shrock, Proc. Ind. Acad. Sci. **1928**: 137-139.

character on the southwestern homoclinal flank of the anticlinal fold extending between the Cincinnati and Wisconsin domes. The altitude of the limestone in the quarry south of Wolcott is about 750 feet. The same formation along the Tippecanoe River in the vicinity of Monticello, 15 miles east, is about 600 feet. At Monon, 15 miles northeast, the same limestone, apparently, occurs at an altitude of 675 feet and at Remington, 10 miles northwest, it is about 650 feet—based upon outcrops of the New Albany shale which overlies the Devonian limestone. Thus it is seen that the quarry outcrop 5 miles south of Wolcott is about 150 feet higher than outcrops 15 miles east; about 75 feet higher than outcrops 15 miles northeast; and about 100 feet higher than the same formation 10 miles northwest. The extent of this limestone as shown on the geologic map accompanying this report is only suggestive. The authors were informed that limestone similar to that in the quarry south of Wolcott lies just beneath the level drift surface about one mile southeast of the same village. This statement could not be verified, but it is quite likely that it may be found there, whereupon the extent of the Devonian limestone within the overlying New Albany shale area would be extended considerably.

Monon Exposures. The Devonian is represented at Monon by a crystalline limestone which contains a number of typical Devonian fossils, and which overlaps the Niagaran disconformably (Cummings and Shrock, 1928, 112). This limestone may be seen outcropping along a small stream in the tourist camp. On the accompanying map (Figure 1) it is considered to be of the same age as the Devonian limestone at Rensselaer and very likely the same as that south of Wolcott.

Alter's Quarry, ¼ Miles Northeast of Remington. At the present time Mr. L. S. Alter is operating a small quarry along Alter's Branch in the N. W. ¼ of Section 21, T. 27 N., R. 7 W. The following section was measured at and near the quarry:

5.	Badly weathered, buff-colored, impure flaggy limestone	2′
4.	Greenish-gray calcareous shale	1½′
3.	Gray shale with thin impure limestone layers	1½′
2.	Hard, bluish-gray limestone with green mottling. Goniatite (?) and Orthoceratite cephalopods were procured from this bed	4½′
1.	Gray blue fissile shale with thin layers of black carbonaceous shale	5′
	Total	14½′

The limestone which is quarried is No. 2 of the section. It is persistently 42 inches thick throughout the rather extensive shallow quarry. No dip is perceptible. A system of east-west joints is conspicuous. The lithic characteristics and the several specimens of cephalopods which have been taken from this bed at once strongly suggest the Rockford limestone of southern Indiana.

Mr. Alter stated that he encountered 80 feet of stone similar to No. 1 of the above section in a well drilled near his dwelling. This is very likely the same stone as the 85 feet of shale, beginning 5 feet below the surface, which was found in a well at Remington (Logan, 1926, 280).

The limestone in this section is mapped as Harrodsburg on Blatchley's map and the shale as Borden (Knobstone),[2] but from the faunal and lithic

[2]Collett (1883a, 69-70) gives a section at Alter's quarry, but it differs considerably from that given above. He also lists a number of fossils from the same locality

characteristics of the limestone, and the stratigraphic relations of the formations to nearby exposures, it seems to be more nearly correlative with the thin Rockford limestone of southern Indiana.[3] The underlying shale would then be New Albany. Such a correlation seems reasonable, since the New Albany shale, overlaid by Mansfield sandstone, is exposed three miles due east along Carpenter's Creek at about the same altitude. (Figure 1.)

The shale and the impure yellow limestone overlying the hard quarry ledge at the Alter quarry are regarded as basal Borden (Knobstone) and are probably equivalent to the New Providence in southern Indiana. This correlation is based simply on stratigraphic succession. Small sections of crinoid stems, sparingly present in the impure limestone, were the only fossils noted above the Rockford limestone.

The Alter quarry is unusually interesting because of the three formations exposed in it. One of them, the Rockford limestone, is entirely exposed. This formation has not hitherto been recognized or identified in exposures in northern Indiana.

Limestone very similar to that of the upper part exposed in the Alter quarry has been taken from a number of shallow quarries in the vicinity. All of the openings are now abandoned, however, as the stone is of poor quality and unfitted for the construction of rock roads. One of these old quarries was in the S. E. ¼ of Sec. 18, T. 27 N., R. 7 W., about 1½ miles west and north of the Alter quarry. Another quarry was located about one mile southwest of the Alter quarry in the N. ½ of Sec. 29, T. 27 N., R. 7 W. Several crinoid fragments were found in the impure yellow limestone here. The opening is now filled with water and debris. The limestone is reported to have been quarried to a depth of 14 feet.

Exposures Near Goodland. Several exposures occur in the shallow bed of Cherry Creek south of U. S. Highway 24, about one mile east of Goodland, in Sec. 25, T. 27 N., R. 8 W. These exposures of impure limestone and bluish shale, with the limestone containing numerous small geodes, represent some part of the Borden (Knobstone) somewhat above the exposures in the Alter locality.[4] Under the abutments of the bridge across Cherry Creek on U. S. Highway 24 hard, bluish impure limestone was encountered in excavating. The limestone here thrown out bears a slight resemblance to the Rockford limestone in the Alter quarry, but it more likely represents some part of the calcareous lower part of the Borden in the region. The area of the outcrops on Cherry Creek is indicated as Borden (Knobstone) on the Blatchley geological map of 1904.

About 1½ miles west of Goodland, north of U. S. Highway 24, in the S. W. ¼ of Sec. 22, T. 27 N., R. 8 W., is an old quarry pit about which were found fragments of a soft, yellow, impure limestone. In the crumbling foundations, which mark the sites of two old buildings nearby, are slabs which are reported to have come from this quarry. The stone very closely resembles the impure yellow limestone above the Rockford limestone of the Alter locality. Crinoid stems were the only fossils observed. The authors regard the rock as lower

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[3]Kindle (1901, 561) in speaking of the Devonian of the Wabash area states, "It appears from well sections, however, that the Rockford limestone is absent in this area." Logan (1926, 281), however, interprests 10 feet of limestone in a well in northeastern Jasper County as Rockford limestone.

[4]Collett (1883, 59-60) gives sections at two localities along Cherry Creek, and refers the strata to the Keokuk and Knobstone shales.

Borden and consider it correlative with that in the Alter exposures. Kindle (1904, 413-414) considered this rock as Niagaran, and it is so mapped on Blatchley's 1904 map.

Exposures near Remington. In the center of the N. ½ of Sec. 34, T. 27 N., R. 7 W. a small quarry, now filled with water, has been opened in a very argillaceous limestone of buff color. Thin layers of gray sandy shale are intercalated with the layers of impure limestone. About seven feet of the stone, thin-bedded and badly weathered, may be seen about the edges of the quarry. Small geodes are common, and several crinoid plates, corals, and a small neotremate brachiopod were found.

About three-fourths of a mile southwest of the above quarry, in the southwest quarter of the same section, a gray argillaceous limestone with intercalated layers of gray sandy shale has been quarried. The stone seems to be the same as that in the quarry to the north.

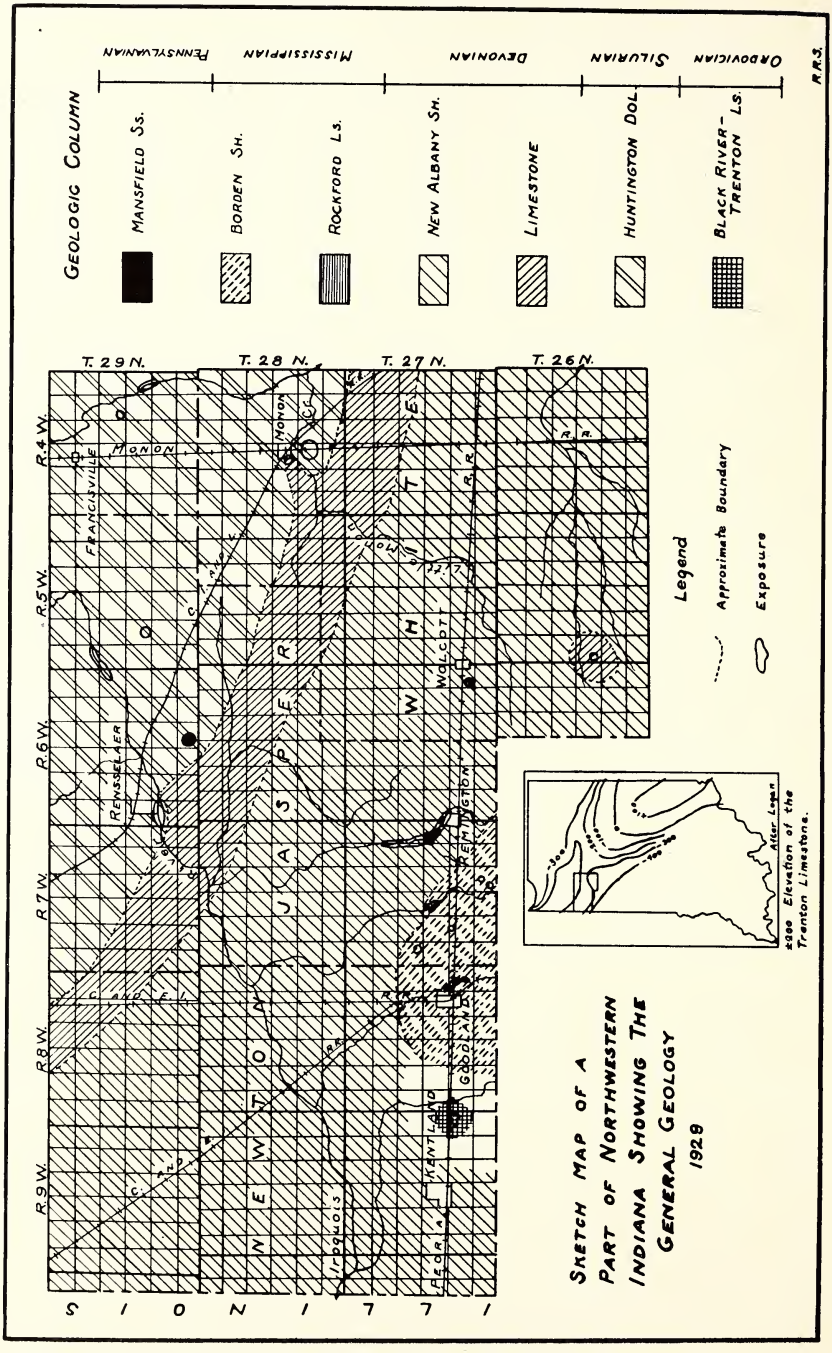
The rock in these two quarries is mapped as Harrodsburg on Blatchley's map, but the lithologic character of the thin impure limestone beds, as well as their stratigraphic relations, points towards the conclusion that they are lentils in the Borden (Knobstone) rather than representatives of the Harrodsburg limestone. They are shown as such on the sketch map. (Figure 1.)

North and northwest of Remington along Carpenter's Creek the New Albany shale is well exposed in the creek bed and in the sides of the valley. Perhaps as much as 20 feet of the dark, fissile shale, locally charged with pyrite, is exposed. Between two prominent outcrops of the shale just northwest of Remington is a narrow area, along the banks of the creek, of a coarse, gritty sandstone of a rather friable character. This sandstone is no doubt a deposit of Mansfield sandstone of Pottsville age in an old channel area in the New Albany shale. It has been well described by Kindle (1904, 416), and it is shown on the Blatchley geological map. It is of more than local interest for it well illustrates the overlapping basal Pennsylvanian resting on a formation far below it stratigraphically. It is an outlier far from the main mass to which it belongs. Again it is another of the many formations which is barely glimpsed in a small exposure in this region of geological surprises, where a mantle of drift barely fails to cover the entire area.

The Geological Map. The small geological map (Figure 1) accompanying this paper was constructed on the basis of the above conclusions, and differs considerably from the same section shown on the map published by Blatchley in 1904.

The rock exposed east of Kentland is mapped as Ordovician instead of Silurian; Devonian limestone is mapped at two new localities, and its area increased; the area of the New Albany shale is shown extending to the State line (so shown because of well data); a small area of the Rockford limestone is outlined; the area of the Borden (Knobstone) is reduced in size; and no Harrodsburg (Warsaw) limestone is shown. Attention should be called to the fact that a blank area is left between the Ordovician area east of Kentland and the surrounding formations. This has been deemed advisable since nothing is known about the relations at the contact between the Ordovician and the overlying rock.

It may be stated that this area lies on the south flank of the geanticlinal axis between the Michigan and Illinois basins, hence the beds show a more or less gentle dip in a direction slightly west of south, except east of Kentland where structural complications are present, and perhaps also in the area of the struc-


GEOLOGIC COLUMN
PENNSYLVANIAN
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
MANSFIELD SS.
BORDEN SH.
ROCKFORD LS.
NEW ALBANY SH.
LIMESTONE
HUNTINGTON DOL.
BLACK RIVER-TRENTON LS.
R.R.S.
T. 29 N.
T. 28 N.
T. 27 N.
T. 26 N.
R. 4 W.
R. 5 W.
R. 6 W.
R. 7 W.
R. 8 W.
R. 9 W.
NEWTON
JASPER
WHITE
FRANCESVILLE
MONON
REMINGTON
WOLCOTT
KENTLAND
GOODLAND
ROSELAWN
LOGANSPORT
Legend
Approximate Boundary
Exposure
±200 Elevation of the Trenton Limestone.
After Logan.
SKETCH MAP OF A PART OF NORTHWESTERN INDIANA SHOWING THE GENERAL GEOLOGY 1928

tural high indicated by the Devonian limestone 5 miles south of Wolcott.

Summary. This paper may be summarized in the following statements:

1. The rocks exposed in the three quarries east of Kentland are of Black River-Trenton age (Middle Ordovician), and represent the oldest rock exposed in Indiana.

2. The exposures of limestone and shale occurring along Alter's Branch, and in the immediate vicinity, between Goodland and Remington are thought to belong to three different geological formations: The New Albany shale, the Rockford limestone and the Borden (Knobstone) shales; rather than Borden (Knobstone) and Harrodsburg as they have been mapped heretofore. The Rockford limestone is recognized for the first time in the exposures in northern Indiana.

3. The exposures in the two small quarries in section 34, two and one-half miles southwest of Remington are thought to be limestone lentils in the Borden rather than Harrodsburg as they have been mapped.

4. Exposures of undoubted Devonian limestone, probably Onondaga, at Monon and in a quarry five miles south of Wolcott give further information on the extent of the Devonian limestones, and indicate a probable anticlinal structure of some considerable size.

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AERIAL PHOTOGRAPHS OF JENNINGS COUNTY

T. M. BUSHNELL, Purdue University

On November 5th, 6th and 8th, 1929, Jennings County, Indiana was photographed from an airplane flying at an altitude of about 13,400 feet. These photographs were taken for the use of the Indiana Soil Survey, which is a cooperative project of Purdue University Agricultural Experiment Station and the U. S. Bureau of Chemistry and Soils.

As far as is known, this is the first case where an entire county has been covered by aerial photos expressly for Soil Survey or where such pictures were available for an entire Soil Survey area. Aerial photos have previously been tried in a small way in Soil Survey, and have been used very extensively in topographic surveys, etc.

An Eastman camera with a 10 inch focal length lens was used. Four hundred and thirty-three negatives were made on a scale of about 4 inches equals one mile. The pictures overlap 50% in flight strip and 25% between strips. Each picture covers about 4 square miles. One square inch of picture shows 40 acres of land. Each point on the ground is reproduced on several pictures.

This task was completed in three flights on three perfectly cloudless days. The pictures were all taken between 10 A. M. and 2 P. M. Panchromatic, hypersensitized film and a ray filter were used, so that the effects of autumn haze were eliminated, and true color values are shown in the pictures.

The photographic plane had to have a powerful motor to carry a pilot, photographer and heavy camera to such high altitudes. The flights were made from Bowman Field, Louisville, Kentucky. A Paulin altimeter was used.

This work was done on contract, the cost being $1,980 or about $5.00 per square mile, as the area of Jennings County is 383 square miles.

The map being made of Jennings County is controlled by (1) three triangulation stations and 7 reference points established by the U. S. Coast and Geodetic Survey, (2) by profiles of railroads, (3) by profiles of State Highways No. 7 and No. 50, (4) by plane table traverse around and across the county at several points.

The grid of section lines is being developed from this control and from the aerial photographs on a scale of 2″ equals one mile. Details of the map are sketched on the scale of the photographs and will be adjusted to the 2 inch to the mile base.

It is obvious that this soil map should be more consistently accurate and dependable than any similar map made without use of photos. It will have a *permanent* value which means *real economy* even if the cost should be increased. However, use of the aerial photos may *cut* the unit cost of Soil Survey even while improving the quality of the work. This saving should be effected by increased speed which will come with experience and skill in using the new technique.

In addition to the value of aerial photographs as a direct aid in making Soil Surveys, they will also be on file as a permanent reference for facts about the land which cannot be represented on soil maps.

The photos may also serve Purdue in any Farm Management, Forestry, statistical or other studies which may be made in Jennings County.

They contain a wealth of information which would be valuable to the Conservation and Highway departments of this state.

They could save more than their cost by benefits to public work now going on. They form a historical record which will be more appreciated a hundred years from now than at present as they show in an accurate, unbiased manner every road, stream, field, house and tree in the county.

George Rogers Clark looked ahead and the results of his efforts made history. It would be in harmony with his attitude if a sum equal to the cost of his memorial were made an endowment for a program of aerial photography. Five per cent interest on that amount could pay for photographing the entire state of Indiana from the air every three years and thereby write in a pictorial record a continuous history of the development and changes of our farms, forests, highways and cities.

THE RELATION OF GEOLOGIC STRUCTURES IN INDIANA TO THE ISOMAGNETIC LINES OF VERTICAL INTENSITY AND TO THE ANOMALIES OF MAGNETIC INTENSITY

W. N. Logan

The relation of the structural features of Indiana which have resulted in the accumulation of petroleum and natural gas to the areas of normal vertical magnetic intensity and to the anomalic areas presents a problem of interest to the geologist.

The main structural features of Indiana include an anticlinal area separating two synclinal areas. The Northwestern arm of the Cincinnati Arch crosses Indiana from Dearborn County to Lake County. The Arch is divisible into three portions. The first is an elevated region which extends from the Cincinnati area to the southeastern part of Cass County. This elevated region forms a plunging anticlinal area extending northwesterly. This elevated region is succeeded on the northwest by a depressed area in the vicinity of Logansport. The latter has a width of about twenty miles. Within the depression the surface of the Trenton limestone lies three hundred or more feet below sea level.

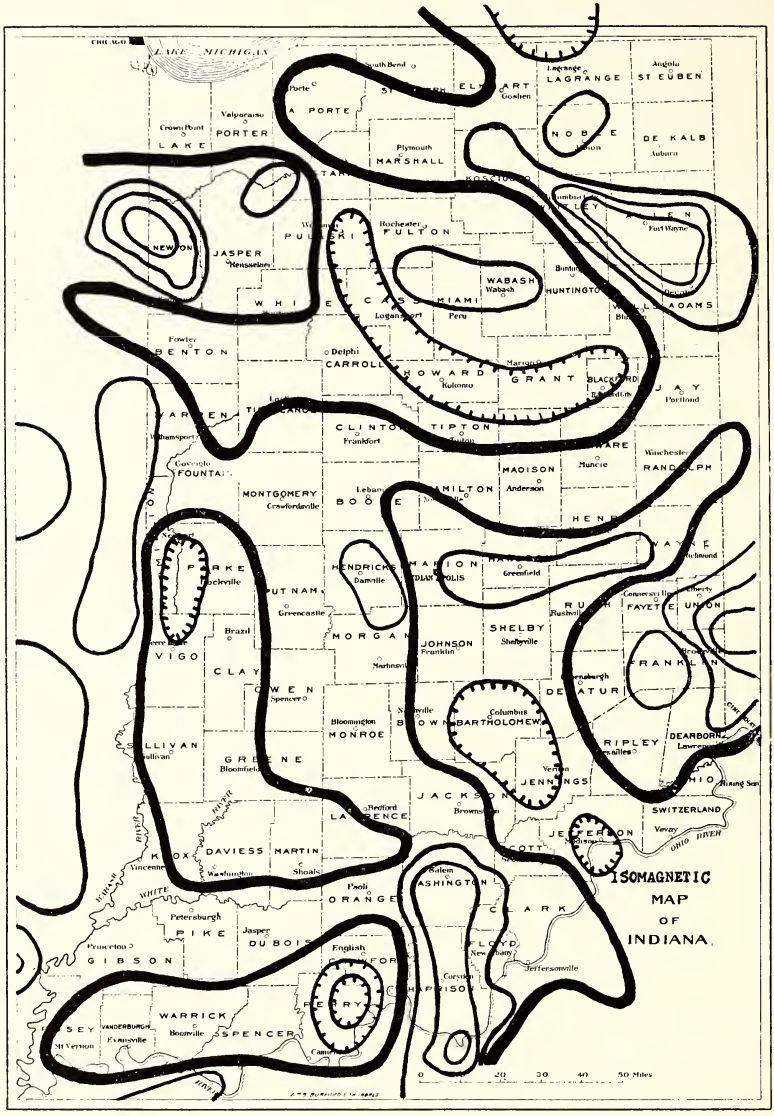
Beyond the depressed area the surface of the Trenton rises until it reaches a height of less than two hundred feet below sea level. Accumulations of petroleum and natural gas in Indiana are definitely connected with the principal anticlinal area and with structural irregularities in the synclinal areas.

In a causal survey of the structural features of Indiana and of areas of normal and anomalic intensity one may get the impression that there is little little relation between structure and vertical magnetic intensity. The more prominent structural areas are crossed by areas of normal intensity and by anomalic areas.

Eastern Indiana (Trenton) Oil Field. This oil producing area lies in the northeastern part of Indiana. Oil production was obtained from parts of Grant, Wells, Adams, Huntington, Jay, Blackford, Randolph, Delaware and Madison counties. Natural gas was obtained from Grant, Blackford, Jay, Delaware, Henry and Hancock counties.

Structural conditions. This entire field lies in an area in which the upper surface of the Trenton limestone lies between sea level and less than one hundred feet below sea level. The main area lies also in an area of normal vertical magnetic intensity. A small oil producing region in northeastern Grant and in northern Blackford counties lies within an anomalic area. A portion of the natural gas territory in southwestern Blackford, in southeastern Grant, in northwestern Delaware, and in northeastern Madison counties lies within an anomalic area.

Other areas connected with the Cincinnati Arch. A small gas bearing area in the northwestern part of Hamilton County in which the surface of the Trenton is approximately one hundred feet below sea level is in a region of normal vertical magnetic intensity. This area is southwest of the axis of the Cincinnati Arch. A gas producing area in the southern part of Howard and the northern part of Tipton counties lies near the axis of the arch. It is within an area of normal vertical magnetic intensity.



In Miami County a small oil field near Peru lies within an anomalic area. Structurally this area lies about two hundred feet below sea level for the upper surface of the Trenton limestone. A small oil producing area lies in the northwestern part of Cass County. The surface of the Trenton lies about three hundred feet below sea level. This region is included in an anomalic area.

A small oil field in the southern part of Laporte County lies within an anomalic area. Using the Trenton limestone as a key horizon it lies about 200 feet below sea level and is northwest of the axis of the arch.

A small oil producing area in the eastern part of Jasper County lies within an area in which the upper surface of the Trenton limestone is less than two hundred feet below sea level and where the area is approximately on the axis of the arch. This area lies within an area of normal vertical intensity but near an anomalic area. In the northwestern part of Jasper County there is a small oil producing area where the surface of the Trenton limesone lies at an elevation of less than two hundred feet below sea level.

At Plymouth in Marshall County some natural gas has been obtained. The upper surface of the Trenton limestone in that region lies between five hundred and six hundred feet below sea level. The area lies within a region of normal vertical magnetic intensity.

In the northern part of Adams County in which the upper surface of the Trenton limestone lies between three hundred and six hundred feet below sea level and an oil producing area lies within an anomalic region. This area lies northeast of the axis of the arch.

Two gas producing areas in Decatur County lie southwest of the axis of the arch. The upper surface of the Trenton limestone in the region lies near sea level. These areas are both in regions of normal vertical magnetic intensities.

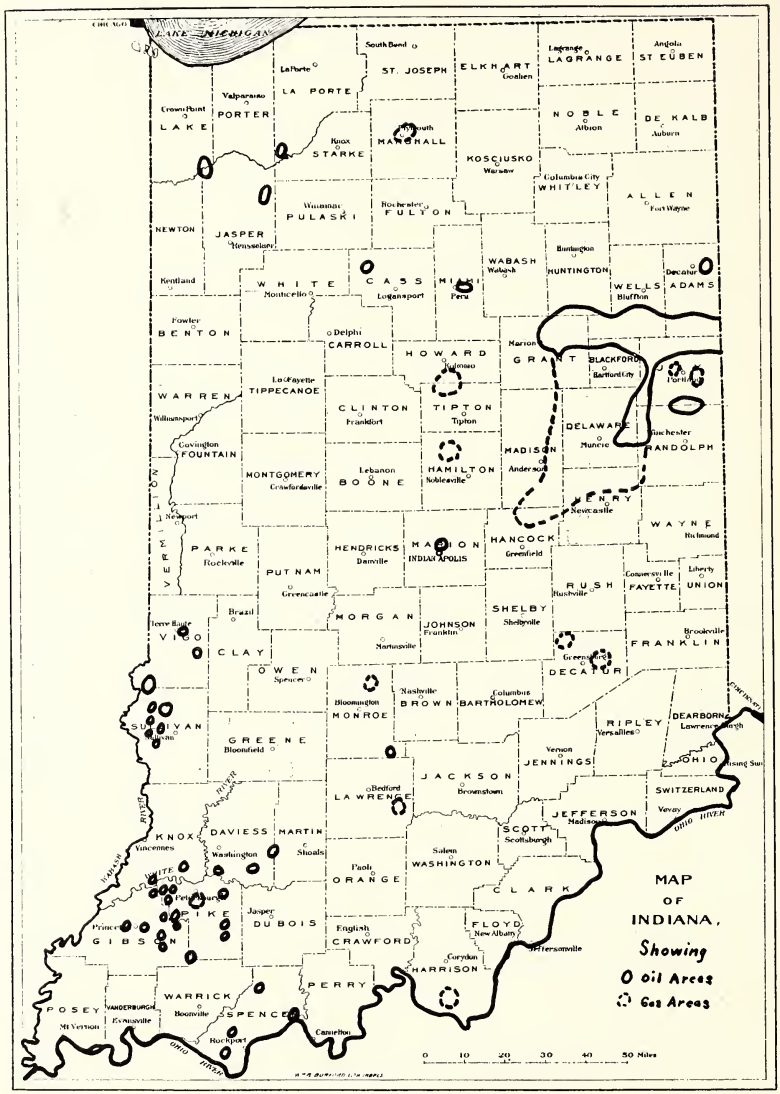
A small gas producing area in the northern part of Jennings County lies within an anomalic area. The upper surface of the Trenton limestone in the region lies at an elevation of about 200 feet below sea level. A small oil producing area in the northern part of Marion County lies within an anomalic area in which the surface of the Trenton limestone lies about two hundred feet below sea level.

The Southwestern Indiana Oil Fields. The oil fields of this region lie southwest of the Cincinnati Arch in a general synclinal area. Production of oil or gas has been obtained in the following counties: Lawrence, Monroe, Martin, Daviess, Knox, Gibson, Pike, Vigo, Sullivan, Spencer and Warrick.

In Monroe County small amounts of oil and gas have been produced in vicinity of the Mt. Carmel Fault in the eastern part of the county. In this area the upper surface of the Trenton limestone lies at an elevation of 900 to 1,000 feet below sea level. The productive areas lie between lines of normal vertical magnetic intensities. In Lawrence County small quantities of gas and showings of oil have been obtained in the eastern part of the county in a similar relation to the fault line. The elevation of the upper surface of the Trenton limestone lies at an elevation of about 1,100 feet below sea level. This area also lies between lines of normal vertical magnetic intensities.

In Harrison County there is a natural gas field which has been producing for many years. A small quantity of oil has been found in the area. In this field the surface of the Trenton limestone lies at an elevation of 1,000 to 1,200 feet below sea level. The entire producing area lies within an anomalic region.

Spencer County contains some small producing areas distributed in several parts of the county. The Gentryville pool is in the northwestern part, a small pool in the southeastern part and two small pools in the southern part of the county. All of these producing areas lie within lines of normal vertical magnetic intensities. Well records which extend to the Trenton are not abundant in this portion of the state. Estimates based on higher key horizons indicated that the upper surface of the Trenton in the eastern part of the county may be 2,700 feet below sea level and that in the western portion it may be as low as 3,400 feet below sea level.



The Tri-County oil pool lies in parts of three counties, Warrick, Pike, and Gibson. A line of normal vertical magnetic intensity passes through this area. Its probable elevation on the upper surface of the Trenton is 3,800 feet below sea level.

Martin County contains a small oil and gas producing area at Loogootee. This field lies within an area enclosed by lines of normal vertical magnetic intensities. In Daviess County there are two oil producing areas, the Cannelsburg, and the Jacobs. These two pools lie within an area enclosed by lines of normal vertical magnetic intensity.

Pike County contains many producing areas, Oakland City, Tri-county, Alford, Barker, Bowman, Davidson, Oatsville, and Rogers Station. These all occur between lines bounding areas of normal vertical magnetic intensities.

Gibson County contains the following producing areas: West Princeton, East Princeton, Francisco, Barrett or South Francisco, McDonald, Hoover, Mt. Olympus, Wheeling and Hightower. These pools are all located between lines of normal vertical magnetic intensities which surround areas of that type.

Two small oil producing areas have been found in Knox County, one at Monroe City and the other at Decker. These are both within areas of normal vertical magnetic intensities.

Sullivan County contains many small oil or gas producing areas, as follows: Shelburn, Heims, Dodds Bridge, Denny, Harmon, Bragdon, Edwards, Scott, and Siosi. These all lie within an area bounded by a line representing normal vertical magnetic intensity.

In Vigo County there are three oil or gas producing areas, one at Terre Haute, one near Riley, and one in the southwestern part, the Siosi. The last two are within areas of normal vertical intensity. The last name is within or near an anomalic area.

Oil and Gas Pools in Areas of Normal Vertical Magnetic Intensities.

The following oil and gas producing areas lie within areas of normal vertical magnetic intensity:

1. Laport County, the Wilder oil pool in the southern part of the county.
2. Adams County, an oil producing area in the southern part of the county.
3. Wells County, an oil producing area in the southern part of the county.
4. Grant County, an oil producing area in the northeastern part of the county.
5. Jay County, a gas producing area near Portland.
6. Jay County, an oil producing area in the western part of the county.
7. Randolph County, the Hotmire oil pool in the northern part of the county.
8. Decatur County, gas producing area near Greensburg.
9. Decatur County, gas producing area near St. Paul.
10. Lawrence County, a gas producing area near the Dennison School.
11. Monroe County, a gas bearing area in Benton Township.
12. Monroe County, an oil bearing area in Polk Township.
13. Martin County, a Loogootee gas and oil bearing area.
14. Daviess County, an oil producing area near Cannelsburg.
15. Daviess County, an oil producing area near Jacobs.
16. Knox County, an oil producing area near Monroe City.
17. Knox County, an oil bearing area near Decker.
18. Gibson County, the West Princeton oil producing area.
19. Gibson County, the East Princeton oil producing area.
20. Gibson County, the Mt. Olympus oil and gas producing area.
21. Gibson County, the Francisco oil producing area.
22. Gibson County, the South Francisco oil producing area.
23. Gibson County, the McDonald oil producing area.
24. Gibson County, the Hoover gas and oil bearing area.
25. Gibson County, the Wheeling oil bearing area.
26. Gibson County, the Hightower oil bearing area.
27. Pike County, the Oakland City oil producing area.

28. Pike County, the Tri-county oil producing area.
29. Pike County, the Barker oil producing area.
30. Pike County, the Bowman oil producing area.
31. Pike County, the Davidson oil producing area.
32. Pike County, the Oatsville oil producing area.
33. Pike County, the Rogers Station oil bearing area.
34. Pike County, the Petersburg gas area.
35. Sullivan County, the Shelburn oil and gas area.
36. Sullivan County, the Heims oil bearing area.
37. Sullivan County, the Dodds Bridge oil producing area.
38. Sullivan County, the Denny oil producing area.
39. Sullivan County, the Harmon oil producing area.
40. Sullivan County, the Bragdon oil producing area.
41. Sullivan County, the Scott oil bearing area.
42. Vigo County, the Siosi oil producing area.
43. Vigo County, the Riley oil producing area.
44. Spencer County, the Gentryville oil producing area.
45. Spencer County, the Maxville oil producing area.
46. Spencer County, the Patronville oil producing area.
47. Spencer County, the Stoessel oil producing area.
48. Spencer County, the Stuteville oil producing area.

The grouping of small pools which lie near each other and which might be considered as parts of a general structure would not greatly reduce the number of oil or gas bearing areas within areas of normal vertical magnetic intensities.

The isomagnetic map accompanying this report was enlarged from a small tracing supplied by Mr. G. B. Somers.

NOTES ON UNEARTHING PARTS OF A MASTODON SKELETON

EDWARD KINTNER, Manchester College

In the summer of 1925 while plowing one of his fields rather deeply, the plow of Mr. Noah Cover struck some solid object buried in the ground. He investigated and found that the object was the femur of a mastodon. In a similar manner he discovered half of the lower jaw, the lower portion of the skull, and some teeth and ribs. Most of these he turned over to the Peru Museum. Nothing further was done toward a systematic search for more of these fossil bones till Oct. 19, 1929, when a party of teachers and students from Manchester College spent a day in excavating.

Mr. Cover's farm lies about a dozen miles north of Peru and consists in part of old lake beds. Toward the west side of the farm was located, until recent years, a small lake covering perhaps twenty or thirty acres. To the northeast of

this was a larger lake that at one time was probably more than a mile in length, and, at places, half as wide. Connecting these two lakes was a narrow strip of water about a hundred yards in width at its narrowest place, and probably three or four times as long. Twenty-five or thirty years ago a ditch was dug through the lakes, completely draining them. Some fossil elk bones were recovered when the ditch was dug. It seems possible that animals in passing from one of these lakes to the other followed the shore-line of the strait connecting them, the ground on either side of this strait being somewhat higher, though the upward slope for the most part is very gradual. It was on the south-east side of this strait at about its mid-point that the mastodon bones were found. The soil at this point is typical of similar situations, being for the most part muck with here and there slight admixtures of heavier soil. It varies from two and a half to three feet in depth and is underlain by quick-sand of unknown depth. Our facilities for going into this were inadquate and we did not attempt to dig into the quicksand except in certain places.

The plan of attack was to start in the vicinity of the place where bones had previously been found and to work over the soil to as great a depth as seemed advisable and over as great an area as possible. The first bones found were located at a depth of about a foot, and others were situated at depths varying from this to about three feet below the surface. In all an area of about fifty by eighty feet was gone over thoroughly. In this space were found ten complete, or nearly complete, vertebrae, sixteen ribs, thirty-two bones from the feet, toes etc., and a large number of fragments of various sizes. The largest parts found were a complete pelvis and one tusk with a diameter at its base of seven inches and a length on its greater curvature of ten feet and two inches.

When found the pelvis showed several cracks, so that it could not be removed entire, and the tusk was cracked square across about one-third of the distance from the base. Another break developed at about the middle of the longer piece of the tusk and it required careful handling to prevent its breaking up into a multitude of fragments. Careful wrapping, first with many turns of twine, then

with burlap, combined with great caution in handling, brought the tusk safely to its present resting-place. None of the larger leg bones were found, and only a small piece or two of the skull, a considerable part of this having been found previously.

With a single exception all of the bones were found in the mucky soil, that exception being a small bone found at a depth of a few inches in the quick-sand. At several places considerable digging was done in the quick-sand, but wholly without result with this single exception.

The bones were not arranged in any orderly fashion as one might expect if the animal had mired and perished; but they were scattered over an area several times that which the mastodon would have covered, and somewhat promiscuously, as if carnivorous animals had feasted on the flesh and had scattered the bones; or as if the mastodon's body might have been partially or wholly afloat while the bones dropped here and there as the body disintegrated. But the first hypotheses seems hardly tenable, as there are no tooth marks observable on any of the bones, and the second conjecture may be as wide of the mark.

Most of the bones found were in an excellent state of preservation in spite of the fact that they had lain where they were found for probably several thousand years. The weathering of the soil had undoubtedly brought uneven pressures to bear on the pelvis and the tusk and this accounts for the factures found in them; but in spite of this, their condition was remarkably good when one considers the time element.

Two of the longest ribs give hints of a story that one wishes he might know in its entirety. These two ribs were once broken at about their mid-point and afterward repaired; but the nature of the repair is such as to indicate that the animal was comparatively old at the time and made a rather poor recovery. What was the nature of the accident or the battle that resulted in this injury can only be guessed at.

Whether other parts of the skeleton not found as yet, are hidden near where these have been found, is unknown. Though but one tusk was found, diligent search was made for a considerable distance around the resting place of this one, but to no avail. The one found was perhaps six inches above the quick-sand, and the sand was excavated to a considerable depth, but no trace of another tusk was found. It may be that the missing parts of the skeleton did not fare so well "at the hands of the elements" as did the parts that have been recovered.

The accompanying illustrations show: (1) The Pelvis as it lay after being completely uncovered but before being moved. (2) One side of the pelvis held by Mr. Cover. This will give some idea of its size, Mr. Cover being an average-sized man. (3) The tusk after the soil had been removed from over it.

THE PRODUCT OF TWO INTEGRALS

WILL E. EDINGTON, Purdue University

Consider two integrals $\int P(x)dx$ and $\int Q(x)dx$, where $P(x)$ and $Q(x)$ are continuous functions of x possessing derivatives except possibly at a finite number of points. The following is a preliminary study of the product of these two integrals when the following relation is satisfied:

$$\int P(x)dx \int Q(x)dx = k\int P(x)Q(x)dx. \tag{1}$$

k is an arbitrary constant which may be given suitable values in certain developments following that will simplify the results. For the sake of brevity P and Q will be used to represent the functions $P(x)$ and $Q(x)$ respectively, and P' and Q' will stand for their first derivatives.

Differentiating both members of (1) with respect to x gives

$$P\int Qdx + Q\int Pdx = kPQ. \tag{2}$$

Differentiating both members of (2) with respect to x gives finally

$$P'\int Qdx + Q'\int Pdx = k(P'Q+PQ') - 2PQ. \tag{3}$$

Solving for the integrals in (2) and (3) gives

$$\int Pdx = \frac{P^2(2Q-kQ')}{P'Q-PQ'}, \qquad \int Qdx = \frac{Q^2(kP'-2P)}{P'Q-PQ'}. \tag{4}$$

Clearing the first expression of (4) of fractions and rearranging the terms gives

$$P'(kQ^2 - Q\int Qdx) = P(2Q^2 - Q'\int Qdx).$$

$$\text{whence} \quad \frac{P'}{P} = \frac{2Q^2 - Q'\int Qdx}{kQ^2 - Q\int Qdx} \quad \text{and} \quad \log P = \int \frac{2Q^2 - Q'\int Qdx}{kQ^2 - Q\int Qdx}. \tag{5}$$

$$\text{Likewise} \quad \log Q = \int \frac{2P^2 - P'\int Pdx}{kP^2 - P\int Pdx}. \tag{6}$$

The expressions (5) and (6) are in such a form that if only one of the functions P and Q is assumed to be known it may be possible to determine the other function and thus satisfy (1). Since the constant of integration for the right member of (6), say, may be expressed as a logarithm with a negative sign it may then be used as a multiplier of the right member when Q is expressed as an exponential.

First consider the condition under which the right member of (5) is exact. The numerator then must be the exact derivative of the denominator or $2kQQ' - Q'\int Q dx - Q^2 = 2Q^2 - Q'\int Q dx$, whence $\frac{Q'}{Q} = \frac{3}{2k}$ and $Q = e^{\frac{3x}{2K}}$. Substituting this value of Q in the right member of (5) and assuming the constant of integration of $\int Q dx$ to be zero, one finds $P = \frac{1}{3} Cke^{\frac{3x}{K}}$. These values of P and Q satisfy (1). Since P appears on both side of (1) the constant $\frac{1}{3} Ck$ may be divided out and need not appear in the expression for P.

Next consider the case when P = Q. Replacing Q and Q' by P and P' respectively in the first expression of (5), simplifying and integrating, one finds $P = Ce^{\frac{2x}{K}} = Q$, whence (1) becomes $\left[\int e^{\frac{2x}{K}} dx\right]^2 = \int e^{\frac{4x}{K}} dx$.

If one assumes special functions of x for the function Q, say, and substitutes these functions in (5), the integration generally becomes very involved, but may be carried out in some cases by assigning k definite values. A few illustrations of some interest will be given.

Assume $Q = x^m$. Substituting in (5) and simplifying one finds the integration simple and $P = C\left[k(m+1) - x\right]^{-(m+2)}$. However, the solution fails for $m = -1$.

The substitution of these expressions for P and Q in (1) leads to the interesting relation $\int x^m dx \int \frac{dx}{[k(m+1) - x]^{m+2}} = \int \frac{x^m dx}{[k(m+1) - x]^{m+2}}$.

Next assume $Q = e^x \cos x$. Here, upon substituting in (5), one finds that the integration may be readily effected if $k = \frac{1}{2}$ and the special value of P is then found to be $P = C\cot x \csc^2 x$. The generally solution with k arbitrary is very involved and was not carried out.

The substitution of a simple function for Q frequently leads to a complicated expression for P such that $\int P dx$ becomes a difficult problem. Thus $Q = \cos mx$ where m is an arbitrary constant, gives upon setting $k = \frac{1}{m}$, $P = \frac{e^{\frac{mx}{2}} \cos mx}{(\cos mx - \sin mx)^{3/2}}$, from which it is evident that $\int P dx$ is not easy of solution.

As was stated in the beginning this is a preliminary report and work is to be continued with the expectation or hope that the product of two integrals each of which may be integrated by the usual methods may give an integral that does not readily yield to known methods. Also it is hoped that more general properties of P and Q may be determined.

ASTRONOMICAL INTERPRETATIONS OF A FORMULA IN THE THEORY OF INTEGRAL INVARIANTS

OLIVER E. GLENN, Lansdowne, Pa.

This article has been derived from an extensive manuscript by the writer, dealing with celestial mechanics. Although it is developed here as a contribution to the infinitesimal geometry of curves, another field of actualities to which it appertains is that of the permanences enjoyed by the orbit of a heavenly body while undergoing secular and periodic perturbations. Upon the latter subject Laplace* discourses as follows: "The permanency of the mean motions of the planets, and of the greater axes of their orbits, is one of the most remarkable phenomena in the system of the world. All other elements of the planetary ellipses are variable; these ellipses approach to and depart insensibly from the circular form; their inclination to a fixed plane or to the ecliptic augments and diminishes, and their perihelia and nodes are continually changing their places. These variations produced by the mutual actions of the planets on each other, are performed with such extreme slowness that for a number of centuries they are nearly proportional to the times."

A result proved by means of simple analysis in the paper referred to will now be stated. The ideal orbit C, of any revolving body solicited by a central force can always be obtained from the actual perturbed trajectory C′, by transforming the polar equation of the latter as follows:

$$T: r' = r + tP(r), \quad \Theta' = \Theta, \quad (t \doteq o),$$

in which the origin is the center of the attraction and

$$\delta = tP(r) = ar^n + br^{n-1} + \cdots + l.$$

The polynomial tP(r) is determined by methods for curve fitting from n observations, (δ, r), of positions of the body upon C′, where the radius r′ of a point on C′ is connected with r, the intercept upon r′ by C, by the relation $r' = r + \delta$. The coefficients a,..., l are small numbers, otherwise P(r) remains practically arbitrary, its coefficients changing as C′ ranges over the field of its admissible variations. The method holds for any central force.

Although the orbit C itself does not remain invariant under T, the mean motion and the greater axis (in the case of a planet) and an extensive system of other functions, some capable of simple geometric interpretation, remain unaltered. These functions are the quantities which stay permanent in the fluctuating orbital configuration.

Two of these invariant functions claim our attention. These constitute a subset of the whole system, unique for fundamental reasons. They are,

$$(1) \qquad A = \phi dr/P(r), \quad B = \Theta_1 dr, \quad (\Theta_1 = d\Theta/dr).$$

One, viz. B, is universal for all C′; while A varies with C′. Referring to A, B as the characteristic invariants of T the problem which we propose in the following: *To determine all types of orbits C for which the characteristic invariants remain fixed numerically as C′ ranges over the field of perturbations.*

**Exposition du Systême du Monde*, (Transl. by Harte), V. 2, Book IV., Ch. 2, p. 23. (Laplace 1749-1827.)

Kirkwood, Proc. Amer. Phil. Soc., Vol. 22, (1885,) p. 424.

The necessary and sufficient condition is comprised in the invariant equation,

$$\phi dr/P(r) = \Theta_1 dr. \tag{2}$$

Since r in P is the radius vector of points on C, the equation of segment C is

$$\phi \int \frac{dr}{P(r)} = \Theta + \alpha. \tag{3}$$

The constant ϕ is arbitrary and may be chosen so as to simplify numerical coefficients in the relation (3). The elementary forms of this equation will now be enumerated. It is found that they include all stable orbital types that have been discovered in the universe, with telescope or by microscopic means.

(a) When P(r) turns out to be linear or linear to a high degree of approximation (3) may be reduced to the form,

$$r = e^{\theta+\alpha} + a.$$

The curve is, (a = o), a logarithmic spiral.*

(b) If P(r) is a perfect square we obtain

$$b(r+a)^{-1} = \theta + \alpha,$$

and the elementary form of the trajectory, (a = 0), is a reciprocal spiral.

(c) When P(r) takes the form of a perfect cube the orbit is

$$b(r+a)^{-2} = \theta + \alpha,$$

which gives the lituus spiral, (a = o).

As would be inferred from the forms of spiral nebulae neither the spiral of Archimedes nor the parabolic spiral, which have stop-points at or near the origin, can be obtained from (3).

(d) Let P(r) be a quadratic, (n = 2), whose factors are imaginary. The integral may be written,

$$\mathrm{Cot}^{-1} \frac{r+a}{b} = \frac{1}{2}(\theta + \alpha), \tag{4}$$

and three very different cases are to be considered.

(I) First we assume that a, b, r, (a positive), are small infinitesimals; then a^2, b^2, r^2 are, in comparison, respectively, infinitesimals of the second order of magnitude. The formula (4) is equivalent to

$$r = \frac{b^2/a}{1-\cos\varphi} - \frac{r^2}{2a} - \delta, \tag{5}$$

where $\delta = (a^2+b^2)/2a$, $\varphi = \theta + \alpha$,
and this may be written,

$$r + \delta = \frac{b^2/a}{1-(1-\epsilon)\cos\varphi} + \frac{1}{a}\left[\frac{b^2\epsilon\cos\varphi}{(1-\cos\varphi)^2} - \frac{r^2}{2}\right], \tag{6}$$

assuming ϵ to be sufficiently small and positive.

---

*Drawings of the spirals are given in many modern elementary books on the Differential Calculus, but comparatively little is known of the loci of polar equations containing parameters.

Now any ordinate τ of the cartesian arc,

$$y = b\,(\epsilon\cos\varphi)^{1/2} = \tau, \quad \left[\, |\varphi| > \beta > 0, \frac{\pi}{2} > \varphi > -\frac{\pi}{2} \,\right],$$

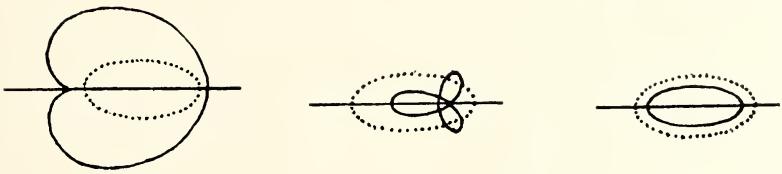
can be brought to differ by as small a positive quantity $h - \tau$ as may be desired from the corresponding ordinate of the line $y = h$ by taking h and ϵ small enough. Then with r sufficiently small the bracket of (6) will approach zero. In fact, from (5) the difference,

$$\frac{(b^2/a\sqrt{2})^2}{(1-\cos\varphi)^2} - \frac{r^2}{2},$$

is of the second order of magnitude, if we exclude from the values of φ a small region around zero. Hence since h becomes less than $b^2/a\sqrt{2}$ by choice of ϵ the bracket in (6) can be made negligible upon a segment C. Then (6) becomes,

$$r + \delta = \frac{b^2/a}{1-(1-\epsilon)\cos\varphi}, \quad (|\varphi| > \beta > 0). \tag{7}$$

If δ is omitted this is a microscopic ellipse. With δ included three possible forms are shown in figure 1. This is the only derivation known to the writer of definite shapes appropriate for plane orbits of electrons.*



(II) Secondly, let us assume that r, in (4) remains very large. An equation (3) is then equivalent to

$$\frac{[(r+a)^2+b^2]^{1/2}}{r+a} = \sec\varphi.$$

We use λr instead of r, λ referring to the choice of linear units, Then,

$$r = \frac{b - a\tan\varphi}{\lambda\tan\varphi}. \tag{8}$$

The hypothesis that r remains large is contradicted by its vanishing for

$$\varphi = \tan^{-1} b/a,$$

except in two cases. The first is when b is small and b/a approximately zero. Then the orbit is nearly circular, having an equation consecutive to $r = -a/\lambda$. The orbits of the planets are large ellipses approximating the circular form, that is with very small eccentricities.

*J. H. Van Vleck, *Quantum Principles and Line Spectra*. Bulletin National Research Council No. 54; Ch. 5, 6, 7.

Next if a = o the equation (8) approximates to

$$(9) \qquad r = b/\tan\varphi, \ (\frac{\pi}{2} - |\varphi| > \beta > 0).$$

With m and e properly chosen this curve is consecutive to a conic

$$r = m/[1 - e\cos\varphi],$$

in the regions where r is large. In fact throughout its length (9), is a type of parabola which passes through the origin. The orbits of comets are parabolas or very long ellipses.

(III) Consider finally instead of (4), the equivalent

$$\tan 1\frac{r+a}{b} = \theta + \alpha,$$

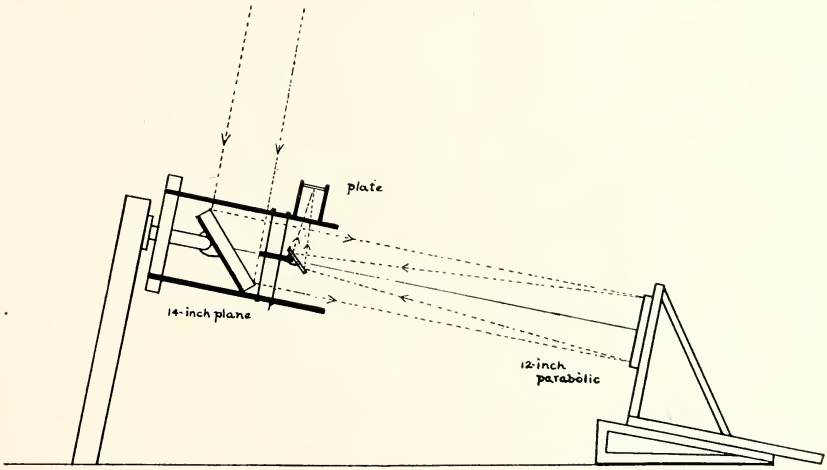
in which r can be of any chosen magnitude. The elementary case is $r = \tan\theta$. It represents a curve of two branches, passing though both the origin and the point infinity. This is not a stable orbit unless it be for an object falling into its center of attraction.

PHOTOGRAPHY OF THE 1929 ECLIPSE WITH A NEW TYPE REFLECTOR

W. A. COGSHALL, Indiana University

It was my good fortune to assist in observing the Total Eclipse of the sun last May 9th, as a member of the United States Naval Observatory party. The instruments used on the regular program were a 65 feet focus camera of 7½ inches aperture, pointed directly at the sun, two cameras of about 11 foot focus and 3½ inches aperture fed by beams from a coelostat, and a large polar axis carrying several short focus cameras.

With the cooperation of the Naval Observatory, I was able to try out a type of instrument which, as far as I know, has never been used. The instrument is a reflector in a coudé form, the polar axis becoming the tube of the telescope or camera. This was especially easy in this case because of the low latitude of the point of observation, 10° 41′.



As indicated in the diagram, the sun light falls on a large plane which turns the beam down the polar axis. At a point about 13 feet distant in this direction, a parabolic mirror of 12 inches aperture and 14 feet focus was placed which converged the light to an image. Near the focus this beam was turned out at right angles and fell on the photographic plate. In order to keep the image on the plate it is of course necessary to rotate the polar axis once in 24 hours, but as indicated in the diagram, there is no necessity for rotating the parabolic mirror, nor really for having any tube except a very short one to carry the two planes. In this case the tube, or polar axis, consisted of a front wheel of an old automobile which had an excellent set of roller bearings. To the rim of the wheel, at equal intervals, three pieces of angle iron, three feet long, were bolted. Small steel rods from these supported the mounting for the small flat in the middle of the beam.

The large plane, 14 inches in diameter, was supported on an adjustable mounting which screwed on in place of the regular hubcap.

The wheel was bolted to the south side of a heavy post, set in the ground at an angle of 10° 40′, and rotated by a long arm which was actuated by a driving clock of the usual form.

The whole thing is extremely simple, inexpensive except for the optical parts, easy to pack, quickly set up and very rapid in its action.

The mirrors were freshly silvered a few days before the eclipse, the final adjustments made in the axis and mirrors and then a few yards of cheap black cotton cloth wrapped around the angle iron tube. An opening was left for the sun light to strike the large plane of course. The plate holder was carried in a square draw tube made of thin wood which was in turn fastened to the angle irons of the tube.

During the eclipse the instrument was operated by Mrs. Cogshall and Mr. J. E. Barker, chief engineer for the Philippine Railway, Mr. Barker changing the plate holders and Mrs. Cogshall starting and stopping the exposures with a circular screen held in the beam in front of the parabolic mirror. A large part of the credit for the success of this part of the program is due Mr. Barker who from the first took great interest in the instrument and during the eclipse while I was busy in the 65 foot camera, took entire charge of its operation.

The instrument worked very beautifully, the images being clear and sharp and entirely free from any astigmatism so commonly feared in the use of plane mirrors.

At a low latitude a much greater focal length could be used with no additional trouble or expense. All that is required is more open air between the rotating part and the parabolic mirror. Even at higher latitudes I am inclined to think it would be worth while to use this form. It may be noticed that for a greater focal length it would work just as well to turn the parts end for end, keeping the moving parts down near the ground and placing the concave mirror at the upper end of the "polar axis." It would be no greater trouble to put the concave mirror on top of a low tower than to put a lens on a high one, and all necessity for a long light tight tube is obviated.

IONIZATION AND THERMAL E. M. F. IN SELENIUM VAPOR

W. T. Sproull and R. E. Martin, Hanover College

PART I.

It is well known that the electrical resistance of properly annealed metallic selenium is decreased by illumination with visible light. One of the leading theories of this action supposes that the light causes a change in the crystalline structure of the selenium.[1] Thus, F. C. Brown[2] suggested in 1911 that the observed phenomena could be explained by assuming that selenium has three cyrstalline forms, A, B, and C. A is non-conducting; B has a conductivity approaching that of the metals, and C has a very low conductivity. The A form has a tendency to pass over into the B form, and the B into the C form, and both of these changes are reversible. The action of the light is to affect the rates at which these transformations proceed, thus changing the relative quantities of the three types present, and so altering the conductivity.

The other leading theory[3] of this light action supposes that the light acts directly on the electronic structure of the selenium, or in other words that the phenomenon is a modified photoelectric effect.[4] The term "photoelectric effect" is here used in a broad sense, including any effect in which light or other electromagnetic radiation acts directly on the orbital electrons, ejecting them from the atom. By 1915, F. C. Brown[5] had come to the conclusion that the annealed selenium may contain "electronic centers, possibly atomic, in an almost unstable condition," and that the light still further lowers the stability, freeing a few electrons temporarily.

For ordinary commercial selenium as obtained from the chemist, however, R. Hamer[6] has found that the photoelectric threshold is 2670°A. It must be remembered that only the specially annealed form of selenium is light sensitive.

With these things in mind, it seemed that if the second theory of the light action in selenium were the correct one, it could be conjectured that the "electronic centers....in an almost unstable condition" might be found in gaseous or vaporized selenium where the great thermal agitation would tend to produce instability.

Consequently, this work was originally undertaken to see if ionization could be produced in selenium vapor by radiation of a longer wave-length than would be expected if selenium were only an ordinary substance without unusual light-sensitive properties. It is to be kept in mind that ionization of selenium vapor, and photoelectric emission from metallic selenium are basically identical processes.[7]

The first step was to see if ionization could be produced with ordinary visible light. A diagram of the apparatus used is shown in figure 1, with the

[1]Berndt, Phys. Zeits. 5., pp. 121-124, 1904. Marc, Zeits. Anorg. Chem. 37, pp. 459-475, 1903; 48. pp. 393-426, 1906.
[2]Phys. Rev. (1), 33. 1, 1911.
[3]Ries, Phys. Zeits. 12. pp. 480-490, 1911.
[4]H. S. Allen "Photo-Electricity," p. 96.
[5]Phys. Rev., (2), 5. p. 404, 1915.
[6]O. S. A., F., 9, pp. 251-257, 1924.
[7]Starling, "Electricity and Magnetism" (4th Edition), p. 582.

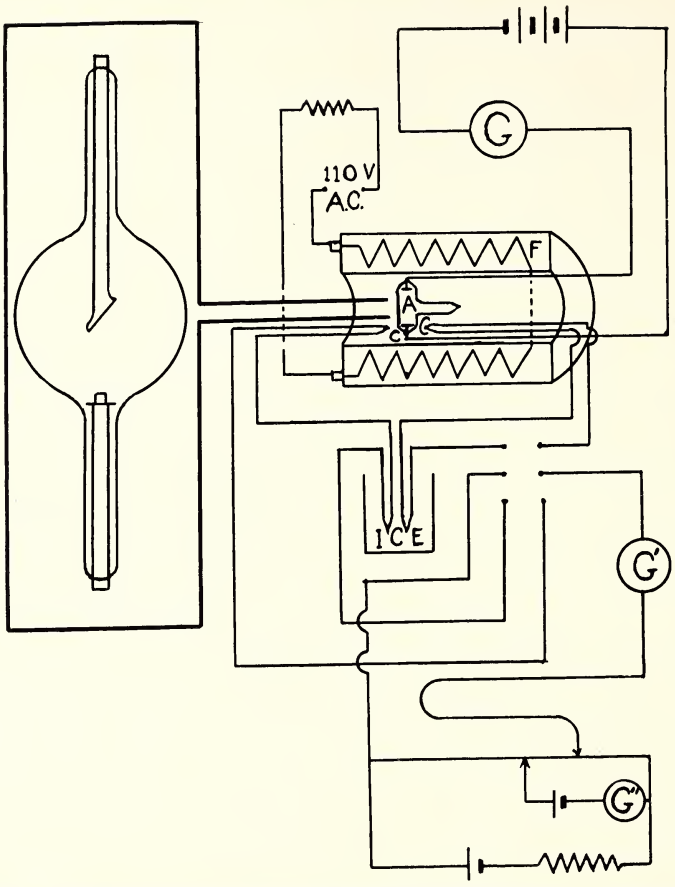


Fig. 1—Diagram of apparatus for producing and measuring ionization in selenium vapor.

exception that a large 1,000 watt incandescent light bulb replaces the X-ray tube shown. F is a cylindrical electric resistance furnace, a longitudinal section being shown in the figure. A is a cylindrical pyrex tube in which the selenium was vaporized. The length of the tube was about 4½ cm., and its diameter about 2 cm. Circular tungsten disks brazed to tungsten lead-in wires formed the electrodes. Immediately outside the tube the tungsten wire was securely bolted to copper wire by means of small brass bolts. The copper wires were connected so as to put the tube in series with a D'Arsonval galvanometer and a storage battery, usually of 240 volts e.m.f. The temperature of the tube was measured by two copper-constantan thermo-couples having the hot junctions, C, C almost against, and on opposite sides of the tube. The e.m.f's of the thermocouples were read with a Leeds & Northrup type K potentiometer.

In studying the problem of the proper quantity of selenium to vaporize in the tube, one must consider the fact that the number of atoms per molecule of vapor varies with pressure and temperature[8] as shown in figure 2, which is due to

[8]Zeits. physical Chem. 1912, 81, p. 129. (G. Preuner and I. Brockmiller).

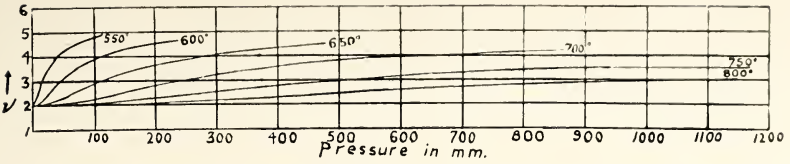


Fig. 2—Curves obtained by Preuner and Brockmiller showing number of atoms per molecule in selenium vapor at various pressures and temperatures.

Preuner and Brockmöller. The proper amount of c.p. selenium was introduced through the side tube, after which the pyrex tube was exhausted of air and sealed off.

The intensity of illumination produced in the tube by the large lamp was measured with a Sharp-Millar portable photometer. The end of the furnace opposite the bulb was closed to prevent air currents, and the interior of the furnace was painted black to prevent reflection.

Trials were then made at various temperatures from 300 to 600°C, to see if any change in galvanometer deflection occurred as the lamp was turned on and off. The first trials showed a marked change in deflection which increased systematically as the lamp was brought nearer to the furnace. However, as a precautionary measure, the trials were repeated with the pyrex tube containing only air, and precisely the same results obtained. It was then obvious that most of the effect, at least, was due to the heating of the pyrex by the intense radiant heat from the huge lamp, the resulting change in the conductivity of the pyrex causing the spurious effect.

A water cell was then inserted between the lamp and the tube, and the experiments repeated. It was then found that no observable change in deflection resulted when the lamp was turned on and off, up to intensities of 3,500 foot-candles. Since the deflection was about 20 cm., and a change of .1 cm. could be easily noted, it was concluded that no ionization was produced sufficient to cause a ½ per cent change in conductivity.

The large bulb and the water cell were then replaced by a Coolidge X-ray tube contained in a heavy lead box fitted with a thick walled lead pipe of about ¼ inch internal diameter. This served to produce a small beam of X-rays which was concentrated on the tube so as to miss the tungsten electrodes by a wide margin as shown in figure 1. The rays striking the tube had a minimum wave-length of about ¼°A. and an intensity of about 1 erg/sec./sq. cm. They produced a marked ionization, causing changes in deflection as high as 40 per cent depending upon the quantity of selenium in the tube and the temperature.

The X-ray tube was then replaced by a quartz mercury arc, and the pyrex tube A, figure 1, by a quartz tube. This quartz tube was shaped like a test tube and the open end was fitted with an asbestos plug through which passed two tungsten wires as electrodes. Since this tube was not perfectly gas tight, sufficient selenium was introduced to keep the tube filled with saturated vapor. The results were the same as with visible light, that is, no change in conductivity as great as ½ per cent was produced.

Due to the fact that the work function involved in the ionization of a gas is, in general, greater than the work function involved in photoelectric emission from the same substance in the solid state, one should not expect any ionization

in selenium vapor until radiations considerably below the 2670°A photoelectric threshold for commercial selenium are reached, *provided* the vapor has no special light sensitive property such as the specially annealed metalic form. One of the strong mercury lines has a wavelength of 2537°A. The fact that ultra violet light of this wave-length produced no ionization indicated that the vapor has no special light sensitive property.

Of course, if the theory that light action in selenium is due to crystalline changes is the correct one, it would be absurd to expect light action in the vapor.

PART II.

During the progress of these experiments, it was found that if the storage battery were removed form the circuit running to the tube, and the circuit now containing only the galvanometer and the tube, were closed, a deflection would result when the temperature of the tube was above about 450°C. Since the tube had been mounted crosswise in the furnace, as shown in figure 1, the opposite ends of the tube could not have varied in temperature by more than two or three hundredths of a degree Centigrade. When the galvanometer was replaced with a Leeds & Northrup type K potentiometer, the e.m.f. was found to be of the order of .01 volt, or 10,000 microvolts. An e.m.f. of this magnitude, in view of the very small temperature difference existing seemed impossible to explain as a thermal e.m.f. However, when the e.m.f. was measured with the tube at various temperatures, and with it containing different quantities of selenium, it was found that the e.m.f. varied quite erratically both in magnitude and direction. Since we were unable to explain it on any other basis, we had to assume that it must be an extraordinarilly large thermal e.m.f.

Going on this assumption, we prepared some new pyrex tubes similar to the old ones, but very much longer, being about 15 inches in length. For electrodes, plain tungsten wire was used without any disk brazed to the ends of the wires. The tube was mounted lengthwise in two electric furances, one end being in one furnace and the other in the other, as shown in figure 3. The gap between the two furnaces was closed with an asbestos apron so as to keep the central part of the tube hot. The tube was filled, in most cases, with sufficient selenium to keep the interior filled with saturated vapor. The electrodes were connected by copper wires to a Leeds & Northrup type K potentiometer, as shown. The open ends of the furnaces were closed, and mercury thermometers inserted so that the bulbs were in contact with the opposite ends of the tube. One furnace was maintained at a constant temperature such that the thermometer read 350° C

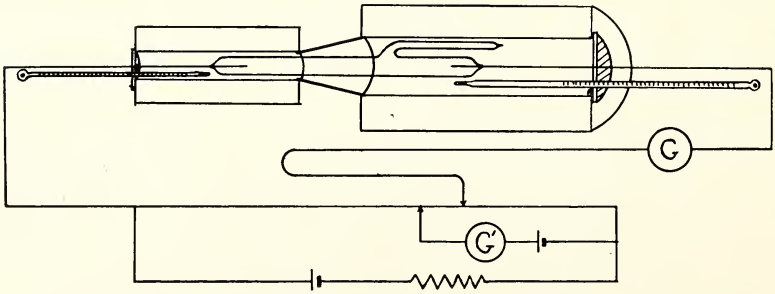


Fig. 3—Diagram of apparatus for measuring thermal e.m.f. in selenium vapor at various temperatures.

The temperature of the other furnace was varied from 470° to 620°C. Below 470°, the resistance of the vapor became so great that the balance point of the potentiometer could not be determined with satisfactory accuracy. At 620°, the pyrex began to melt, so that these two temperatures determined the range of temperature to be used. Since copper lead-in wires were used, the thermal e.m.f. resulting would be between the vapor and copper.

With such a tube filled with sufficient selenium to maintain a saturated vapor, the e.m.f. was carefully measured for various temperatures of the hotter furnace, both while rising and while falling. The values obtained on the first trial are shown in column 3 of the table, the corresponding curve being the one marked by the ⊞ marks in figure 4. This experiment was then repeated after allowing a day or so to elapse, without in any way disturbing the apparatus. In this trial, the values shown in column 4 of the table were obtained, the cor-

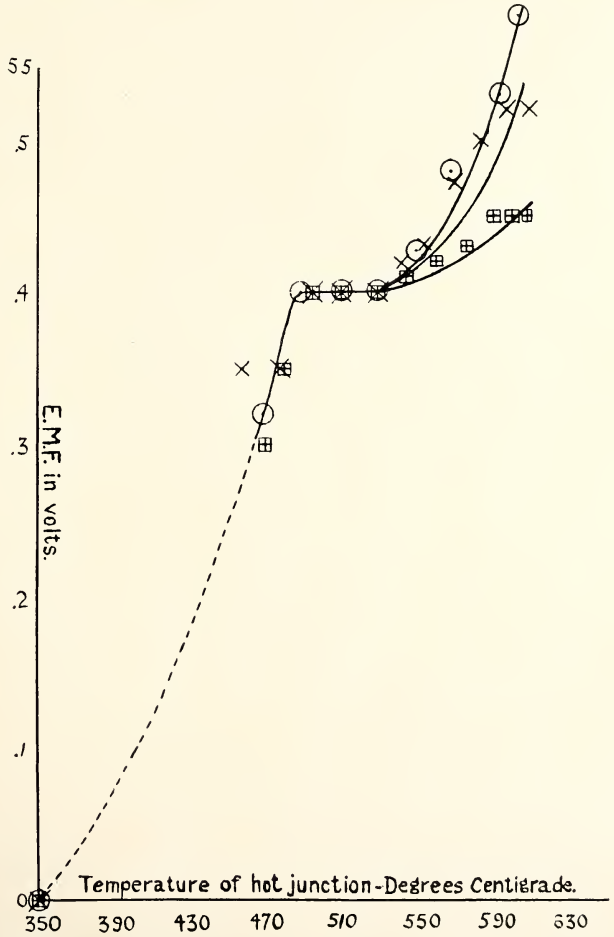
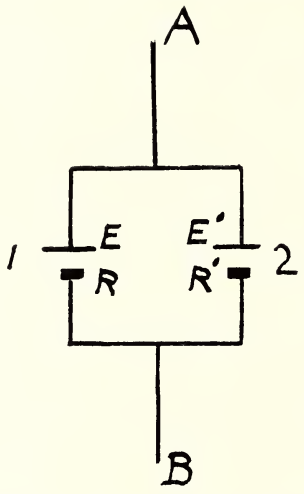


Fig. 4—Thermal e.m.f. curves for selenium vapor against copper showing effect of vapor action on tungsten electrodes.

responding curve being the one marked by X's. A day or so later, without disturbing the apparatus, a third trial was made, and this time the values shown in column 5 were obtained, the corresponding curve being marked with the circles.

Before attempting to explain these curves, it is well to show that these e.m.f's could not have been thermal e.m.f's in the pyrex of the tube. Considering the circuit, one sees that between the electrodes the current has the choice of two parallel routes: (1) Through the vapor, or (2) Through the pyrex. After the trials mentioned above were run, the tube was opened and the selenium entirely expelled by baking in a hot furnace. The trial was then repeated with the empty tube, and it was found to be impossible to accurately balance the potentiometer, for even when the balance was off by as much as ½ volt, a scarcely perceptible galvanometer deflection was produced. This showed clearly that the resistance of the pyrex was at least 50 times that of the vapor.



Let us then consider (Fig. 5) two cells, 1 and 2, in parallel, connected to a potentiometer, which of course draws no current when balanced. Let No. 1 represent the vapor, and let E = its e.m.f. and R = its resistance. Let No 2 represent the pyrex, and let E′ = its e.m.f. and R′ = its resistance. Consider the circuit from A to B (Fig. 5) open. Assume E greater than E′. Then the current flowing through the walls of the tube is given by $\frac{E-E'}{R+R'}$

Thus the potential difference between the electrodes, or between A and B is

$$\frac{E-E'}{R+R'} R' + E'$$

Now if R′ is very large compared to R, as was found to be the case, this p.d. reduces to $E-E'+E'=E$.

Or, assume E′ larger than E. Then the current becomes $\frac{E'-E}{R+R'}$, and the p.d. be-

$\frac{E'-E}{R+R'}$ comes —— $R+E=E$ when R′ is very large compared to R. Thus we see that the potential difference measured between the electrodes by the potentiometer is, within 1 or 3 per cent the actual e.m.f. of the selenium vapor.

After dismantling the apparatus, it was discovered that the tungsten electrodes had entered into a chemical combination with the selenium forming a very heavy coating of a yellowish substance which must have been a selenide of tungsten. In fact, the electrodes had been completely disintegrated into the yellowish powder in some places. This gives a suggestive clue as to the probable explanation of the peculiar shape of the curves above 490°C.

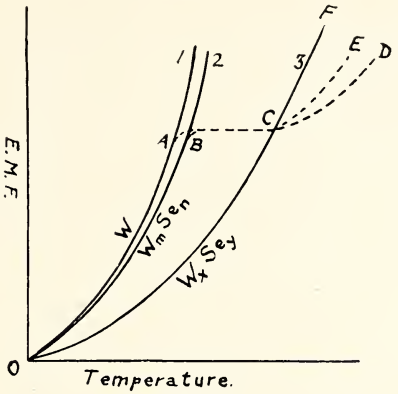


Fig. 6.

After considerable thought, it seemed as though the observed effects could be explained as follows. In figure 6, suppose curve 1 is the e.m.f.-temperature curve with pure tungsten electrodes, and that No. 2 is the curve for some tungsten selenide, $W_m.Se_n$., and that No. 3 is for some other tungsten selenide, W_xSe_y.

In the first trial run, the curve obtained was of a form similar to OACD. It seems likely that at the jpoint A, the tungsten began to combine with the selenium, forming the compound W_xSe_y, and that at the point C, the entire surface had become coated with the selenide, so that the curve CD resulted. As the furnace cooled, it seems that some change began when C was reached again. We can assume that the W_xSe_y began to change into another selenide W_mSe_n, the change being complete when the point B was reached. The curve BO was then followed as the cooling continued. During the second trial, the e.m.f. retraced the curve OB, until at B, the W_mSe_n began to change again into W_xSe_y. However, when C was reached this time, more of the tungsten beneath the surface had combined forming W_xSe_y, so that the e.m.f. was not exactly the same as before, but followed the curve CE. On cooling, the path ECBO was retraced similarly to the first trial. On the third trial, practically the entire electrode had changed to W_xSe_y, giving the curve CF, which is the curve for that compound.

This hypothesis supposes that the curve OA for pure tungsten, and the curve OB for W_mSe_n lie so close together that they appeared as the same curve from the data. It cannot be assumed that the W_xSe_y compound decomposed back

into tungsten and selenium on cooling, for after the tube was cold, it was found that the electrodes had changed completely into the yellow selenide called W_mSe_n in this hypothesis. This theory is the only one which has occurred to us which will explain all of the observed facts.

An attempt was made to see what effect would be produced in the curves by using tubes containing unsaturated selenium vapor. It was found, however, that as soon as a run was attempted with only enough selenium in the tube to form an unsaturated vapor, that the formation of the selenide absorbed so much vapor that the resistance of that vapor remaining became about the same as that of the pyrex walls in the tube so that e.m.f. measurements of any accuracy were impossible. This trouble might be eliminated if some other metal like, say, platinum were used for the electrodes, but since tungsten lead-in wires would have to be sealed in the pyrex, these wires would be attacked by the vapor, and it is not likely that satisfactory results could be obtained.

A trial was also made using saturated mercury vapor in the tube, but even though the furnace was heated until the mercury vapor swelled the tube out of shape, the resistance of the vapor was still so high that no satisfactory measurements could be made.

The results of the experiments on ionization thus lead us to conclude that vaporized selenium has no unusual light sensitive properties such as are found in the specially annealed metallic form. This shows that either (1) light action in the annealed selenium is due to crystalline transformations as suggested by Berndt and Marc, or (2) if the light action *is* a modified photoelectric effect, no "electronic centers.....in an almost unstable condition" are present in the vapor such as those suggested by Brown as existing in the annealed selenium.

The experiments on the thermal e.n.f. of selenium vapor show that the vapor has an unusually high thermoelectric power against tungsten, but that chemical combination between the vapor and the tungsten makes it impossible to obstain the true e.m.f. curve above about 485°C.

TABLE I

Temperatures in degrees C.		E. M. F. in Volts		
Hot Furnace	Cold Furnace	Trial 1	Trial 2	Trial 3
460	358	..	.35	..
470	353	..	..	.32
471	340	.30	..	..
480	352	..	.35	..
482	347	.35	..	..
491	350	..	..	.40
496	350	.40	..	..
498	350	..	.40	..
511	351	.40	..	..
512	351	..	..	.40
512	349	..	.40	..
531	351	.40	..	..
531	347	..	.40	..
531	353	..	..	.40
544	349	..	.42	..
546	351	.41	..	..
552	347	..	..	.43
556	348	..	.43	..
562	350	.42	..	..
570	347	..	..	.48
571	347	..	.47	..
577	347	.43	..	..
585	354	..	.50	..
592	344	.45	..	..
596	350	..	..	.53
600	350	..	.52	..
602	349	.45	..	..
610	352	.45	..	..
611	350	..	.52	..
616	350	..	..	.58

THE ELECTRICAL CONDUCTIVITY OF THE ATMOSPHERE AT TERRE HAUTE, INDIANA

Ira W. Vance and J. F. Mackell, Indiana State Teachers College

Introduction. Experiments having to do with atmospheric electrical conductivity date back to the time of Coulomb, 1785. He showed that if a metallic conductor be placed in air, it would lose its charge gradually, not only on account of faulty insulation but also on account of the conduction of electricity away from the body into the air.

Very little investigation, however, was carried on with reference to atmospheric conductivity for almost a whole century. We know that this is true because as late as 1880 the false idea that damp air conducts electricity better than dry air was very prevalent. As a matter of fact, it is probably an idea which is prevalent today *amongst* laymen and even *amongst* those scientists who are not fully aware of recent investigations upon the subject of atmospheric electricity.

If a metallic conductor, connected with an electroscope, is charged, a current begins to flow from all sides toward it. This can easily be seen by observing the fall in potential registered by the electroscope. If the conductor is charged positively, then negative ions move toward its surface, thus causing in the vicinity an excess of ions of this sign while the positive ions move away from it. In the neighborhood of the surface of the conductor a free space charge of the opposite sign is formed which causes a distortion of the field in that region.

Various methods have been employed in determining the polar conductivity of the atmosphere. In general, it seems that the greater the capacity of the dissipating body relative to that of the connecting rod, the greater will be the proportion between the dissipation and the conductivity. If the dissipating body be placed too near the electroscope free current will not be obtained. On this account it is best to connect the dissipating body to the electroscope by a long wire with a small capacity.

If K is the capacity of the dissipating body alone, C+K the capacity of the dissipating body and the electroscope together, and V, the initial potential of the system, the loss of the whole system per unit time amounts to $(C+K)\frac{dV}{dt}$.

The polar conductivity will be represented by the following equation:

$$\lambda\pm = -\frac{1}{4\pi}\left(\frac{C+K}{KV\pm}\right)\frac{dV}{dt}.$$

Where λ stands for the conductivity and the $+$ sign for λ corresponds to a negative charge on the dissipating body and vice versa, since it is always the ions of the opposite sign that cause the loss of charge of the body.

Description of Apparatus and Method of Procedure. The present experiment was carried out at the Indiana State Teachers College at Terre Haute, both in the Physics Laboratories and at points in the vicinity of the

Science Building during the summer of 1929. The observations were made over a period of about five weeks and since good weather is quite essential for such measurements, observations on the outside could not be made every day. However, enough outside observations were made to enable one to form a fairly definite conclusion as to the average conductivity both for positive and negative ions.

The apparatus consisted of an alpha ray electroscope which had been redesigned expecially for the purpose. In the first place the usual insulated key was found to be entirly too conducting. Therefore, this entire key was removed and a sulphur plug was inserted through which was led a small wire and this wire was connected to the gold leaf system. It was found by several experiments that the leakage due to faulty insulation due to the conductivity of the sulphur was quite negligible when compared to the values which were to be measured.

The electroscope was first calibrated to read in volts. The capacity of the electroscope was then experimentally determined in the following manner:

The electroscope was charged with a negative potential of from 600 to 700 volts. A sphere whose potential was O was brought in contact with the wire connected to the terminal of the electroscope. The quantity of electricity thus distributed itself over both the sphere and the electroscope. The voltage was again noted. From the data thus obtained from a number of observations the capacity of the electroscope was calculated.

If C_1 be the capacity of the electroscope, C_2 the capacity of the sphere, V_1 the potential of the electroscope, V_2 the potential of the combination, then

$$C_1V_1 = (C_1 + C_2)V_2 \therefore C_1 = \frac{C_2V_2}{V_1 - V_2}.$$

Two spheres whose capacities were 1.3 and 1.56 electrostatic units respectively, were used in a set of about twelve observations. A mean value of 3.33 electrostatic units was determined for the capacity of the electroscope.

The electroscope was now set up in the laboratory and an insulated spherical body whose capacity was known was connected to the electroscope by means of a wire, the capacity of which was known. A charge was then placed upon the insulated system and the deflection of the gold leaf of the electroscope was noted. Now the time rate of discharge of the electroscope was taken over a period of several minutes. The electroscope was first charged with one sign and then with the other and comparative values were noted.

The electroscope and the insulated system were now moved to another room and other observations were taken. The results of these observations are shown in the table following.

The electroscope and insulated system were then moved to a point well protected from the earth's field near the Science Building on the east side and again to a point on the west side of the Science Building, out in the open on the ground. Again the electroscope was moved to a point entirely removed from the Science Building and again care was taken to have the electroscope protected from air currents and other disturbing elements. The results of all these observations taken over a period of several days are shown in the table to follow.

It will be noted that one set of observations was taken on August 14 over a period of the entire day. Observations were taken several times during the hour and the mean for each hour of the day is indicated in the table. This was done in order to procure a diurnal curve Again the values for both negative and positive ions were taken.

DATA SHEET

Readings in Open Air

Time	Date	Place of Observation	$\lambda+$	$\lambda-$	$\lambda+ + \lambda-$	$\frac{\lambda+}{\lambda-}$
	Aug. 1	Between S. H. & Library	.93 $\times 10^{-4}$			
P.M. 1-3	Aug. 6	Between S. H. & Library		.99 $\times 10^{-4}$		
P.M. 3-5	Aug. 6	Between S. H. & M. D. Res.	1.04 $\times 10^{-4}$			
P.M. 1-3	Aug. 8	Between S. H. & M. D. Res.		1.05 $\times 10^{-4}$		
P.M. 3-4	Aug. 8	Between S. H. & M. D. Res.	1.08 $\times 10^{-4}$			
P.M. 1-3	Aug. 13	538 North 5th Street	1.11 $\times 10^{-4}$	.87 $\times 10^{-4}$	1.98 $\times 10^{-4}$	1.28
A.M. 6	Aug. 14	538 North 5th Street	1.12 $\times 10^{-4}$	1.2 $\times 10^{-4}$	2.32 $\times 10^{-4}$	.93
A.M. 7	Aug. 14	538 North 5th Street	1.15 $\times 10^{-4}$	1.1 $\times 10^{-4}$	2.25 $\times 10^{-4}$	1.05
A.M. 8	Aug. 14	538 North 5th Street	.90 $\times 10^{-4}$	.9 $\times 10^{-4}$	1.8 $\times 10^{-4}$	1.
A.M. 9	Aug. 14	538 North 5th Street	.926$\times 10^{-4}$	1.08 $\times 10^{-4}$	2.006$\times 10^{-4}$	.86
A.M. 10	Aug. 14	538 North 5th Street	1.01 $\times 10^{-4}$	1.12 $\times 10^{-4}$	2.13 $\times 10^{-4}$	.98
A.M. 11	Aug. 14	538 North 5th Street	1.11 $\times 10^{-4}$	1.03 $\times 10^{-4}$	2.14 $\times 10^{-4}$	1.08
A.M. 12	Aug. 14	538 North 5th Street	1.2 $\times 10^{-4}$	1.15 $\times 10^{-4}$	2.35 $\times 10^{-4}$	1.04
P.M. 1	Aug. 14	538 North 5th Street	.99 $\times 10^{-4}$	.91 $\times 10^{-4}$	1.9 $\times 10^{-4}$	1.09
P.M. 2	Aug. 14	538 North 5th Street	1.01 $\times 10^{-4}$	1.03 $\times 10^{-4}$	2.04 $\times 10^{-4}$	.98
P.M. 3	Aug. 14	538 North 5th Street	1.18 $\times 10^{-4}$	1.07 $\times 10^{-4}$	2.25 $\times 10^{-4}$	1.1
P.M. 4	Aug. 14	538 North 5th Street	1.08 $\times 10^{-4}$	1.13 $\times 10^{-4}$	2.21 $\times 10^{-4}$	.96
P.M. 5	Aug. 14	538 North 5th Street	.91 $\times 10^{-4}$	.91 $\times 10^{-4}$	1.82 $\times 10^{-4}$	1.
		Readings Inside A Room				
P.M. 1-4	July 24	Room S-C-41	.5 $\times 10^{-4}$			
P.M. 1-4	July 26	Room S-C-41		.58 $\times 10^{-4}$		
P.M. 1-4	July 26	Room S-C-50	.48 $\times 10^{-4}$			
P.M. 1-4	July 30	Room S-C-50		.65 $\times 10^{-4}$	1.37 $\times 10^{-4}$	.8

Note: All values for $\lambda+$ and $\lambda-$ are the mean of several values taken within the indicated period.

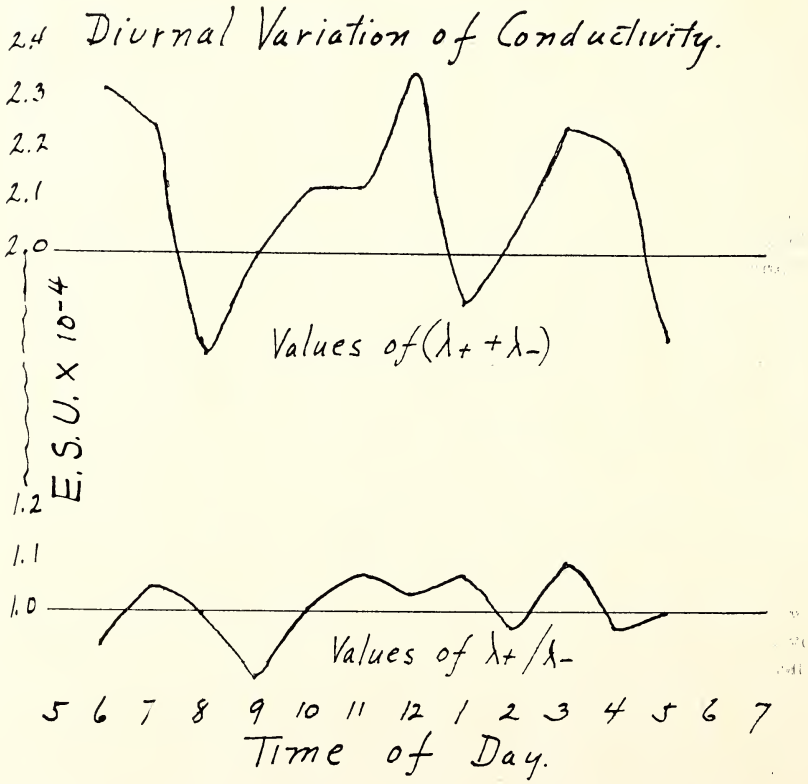
Remarks Concerning the Data Obtained. A study of the data submitted brings forth a few outstanding conclusions. It must be admitted, however, that not enough observations have been made in some instances to warrant any definite conclusions. In the case of the measurements made inside the laboratories it appears that the values of $\lambda+$ and $\lambda-$ are only about one half the values which are found outside, and since the building in which the measurements were made is somewhat filled with a network of pipes, it may be considered as partially shielded from atmospheric electrical effects. Therefore, no definite conclusions should be reached concerning the inside measurements. A further study, however, of these values might bring forth some facts upon which a definite conclusion might be reached.

A study of the values for the outside measurements in the table show that as a general rule the values for $\lambda+$ are greater than for $\lambda-$. This would indicate that there is usually an excess of positive ions in the locality where the observations were made. It may also be noted that the total conductivity $\lambda+ + \lambda-$ within a room, is only about one half of that outside, and the figures show that the values for $\lambda+$ are less than for $\lambda-$. It must be remembered, however, that the values for the conductivity in the laboratory were not obtained over a long enough period of time to be conclusive. The greater part of emphasis, therefore, in this paper should be put upon the values obtained on the outside.

A study of the values obtained for positive and negative conductivities on the outside reveals the fact that here the values for $\lambda+$ are larger than those for $\lambda-$, and this is in agreement with theory and with other experimental values obtained by other investigators.

The sum of the values indicated in the + and − columns may be taken as the total atmospheric conductivity at the time in question. It appears, therefore, that the mean of these values found on the outside is about 2.15 x 10^{-4} electrostatic units. This value is in close agreement with the values found over land in Europe which is about 2.1 x 10^{-4} electrostatic units. According to the measurements of the Department of Terrestrial Magnetism the mean value over the Continent of America is about the same as that of Europe. It may be pointed out, however, that the value obtained by the Department of Terrestrial Magnetism was arrived at by taking the average of several values found over the Continent of North America but the greater number of these observations were made in and around Washington and the Atlantic Sea Coast. Up to the present time no other measurements have been recorded for Indiana. It appears, therefore, that the mean values obtained in this experiment are in very close agreement with those found over Europe and with those found by the Department of Terrestrial Magnetism at Washington.

As was indicated in the Introduction, a series of readings was made over a period of twelve hours beginning at 6:00 a.m. and ending at 6:00 p.m. on August 14. Readings were taken for both the positive and negative values a intervals of about ten minutes. The values thus obtained were averaged for



each hour as is shown in the table and in the curves which follow. Figure 1 shows the diurnal curve for the day mentioned. This curve shows a variation of about $.45 \times 10^{-4}$ electrostatic units from the high period to the low period. The high points for the day are at 6:00 a.m., 12:00 noon, and between 3:00 and 4:00 p.m. The low points occur at 8:00 a.m., 1:00 p.m., and 5:00 p.m.

Further similar study indicates that the conductivity undergoes everywhere a regular daily change which is in general dependent upon the locality. It might be interesting, however, to conduct further studies of this character in the vicinity of the location where this experiment was carried on to see if this locality has a particular type of diurnal curve as regards its atmospheric electrical conductivity.

MISTAKEN IDEAS CONCERNING SOUND ABSORBERS

Arthur L. Foley, Indiana University

There are today so many school rooms, churches, and other buildings that are bad from the standpoint of acoustics, and so many others are being erected with no scientific consideration of the question of what their acoustical properties will prove to be, that it seems to be high time for architects to awaken to the fact that an auditorium is for auditors, that in an auditorium hearing is more important than seeing. Most of them have not yet awakened. We continue to build churches, community buildings and all sorts of assembly rooms utterly unfit for the very purpose for which they are intended. When building a house we would not employ an architect who would plan bed rooms in which one could not comfortably sleep, or kitchens in which good food could not be prepared. But we continue to employ architects to build auditoriums for which we should coin a new word, *spectatoriums*, as the only consideration given the auditor is "how many will the room seat and each one see the pulpit or stage?"

It is not the purpose of this paper to set forth the laws or principles of acoustics by which the architect must be guided in planning a satisfactory auditorium. I wish merely to direct attention to "some mistaken ideas concerning sound absorption," ideas which are more or less general and some of which, I regret to say, have found their way into text books.

(1) *Sound Mirrors.* A fine silver mirror reflects a smaller per cent of the light that falls upon it than an ordinary plaster wall reflects of the sound striking the wall. In other words, an ordinary room with plaster walls, glass windows, wood doors and wood floor is a sound mirror room in which there would be more numerous sound reflections and sound images than there would be light reflections and multiple light images in a room without windows, doors or other openings and having all walls, ceiling and floor of the finest quality of plate glass mirrors. If the floor of the sound room were of cement and the walls of tile or glazed brick, as a sound mirror room it would far surpass the plate glass mirror room for light. In fact, the plate glass mirror room itself would reflect more sound energy than light energy. It is therefore very evident that concave surfaces act as condensing mirrors, and are to be avoided. If present they must be covered with a substance having as high a coefficient of absorption as possible. No amount of sound absorbing material used elsewhere will eliminate the unequal sound distribution such curved surfaces always produce.

(2) *Sound Absorbing Materials.* That a soft, yielding substance is a better sound absorber than one that is hard and rigid is not necessarily true. For instance, what is called sponge rubber (like that of rubber bath sponges) is not as good a sound absorber as is acoustic palster, a hard and comparatively inelastic material. The plaster owes its absorptive properties to its porosity—to the small holes that have been blown in it by gas, chemically formed and escaping while the plaster is setting, or hardening. The sponge rubber appears to be full of pores. A closer examination shows it be be made up of numerous air cells, each entirely enclosed in rubber, and to be practically non-porous. It is therefore a poor sound absorber.

Porosity being the most essential property of a good sound absorber, it should be clear that anything that closes the pores of a substance must materially reduce its ability to absorb sound. The surface of a sound absorbing material can not be covered with varnish or a pigment paint without lowering its sound absorption coefficient. Perhaps it is unnecessary to add that the acoustics of a room can not be improved by placing in it vases, statuary, or anyting made of glass, stone, metal, or any other rigid and non-porous substance. If a hundred miles of wire were stretched back and forth across a room, the improvement in its acoutics would be negligible.

(3) *Sound Absorption of Audience.* Most tables of sound absorption coefficients give a value above 4 units for the absorption of an audience per person, averaging perhaps about 4.7 units. Some tables give 4.5 units per man and 5.4 units per "isolated" women. The latter value might have been about right thirty years ago when women wore a total of forty or fifty yards of drapery, but not today. In a recent publication[1] I have advised that in the case of new talking picture theaters the audience absorption be calculated on the basis of three units per person—a value lower than recommended by others. There are four reasons for recommending so low a value, the first—as mentioned above—being the fact that women and children wear far less clothing than they did when the high absorption values were experimentally obtained. A second reason is that talking picture houses are usually seated, with chairs covered with more or less upholstery, to which the absorbing power of the chair is chiefly due. A person seated in such a chair covers the upholstery, and at the same time the area of his body exposed to sound waves is diminished. A third reason is that talking picture audiences usually include many children, who present less sound absorbing surface than do grown-ups. A fourth reason is that it is highly desirable to reduce the reverberation period of a "talkie theater" to a lower value than is permissible for a church or "legitimate stage" theater. At best reverberation is more or less of a disturbing factor which might best be reduced to the lowest possible limit were it not for the fact that a certain amount of sound reflection is necessary in order for a speaker or actor to make himself heard in a large room. But in the case of talking pictures the volume of the sound can be increased almost at will, so that reverberation is not necessary to give sufficient sound intensity for satisfactory hearing. Consequently for talking picture theaters I am recommending reverberation periods not to exceed one second—considerably lower than text books recommend for theaters and music halls.

(4) *Location of Sound Absorbing Material.* It is frequently stated that the effect of sound absorbing material is independent of where it is placed—whether on walls, ceiling, or floor. The statement is practically true in certain cases only and where reverberation only is considered. Evidently it could not be true for sound distribution in case the room has any sound mirror surfaces, as explained in paragraph (1).

Again, it is practically true only where the sound is produced at considerable distances from the sound absorbing material. As an illustration consider a sound source S (fig. 1) and let us confine our attention to the sound energy emitted from the source between the directions S L and S M, which, when reflected, would pass to the opposite wall between the lines L N and L O. Covering the near wall for a space L M would produce as much sound absorption

[1]Acustics of Talking Picture Theaters. Published by The Starr Piano Company, Richmond, Indiana.

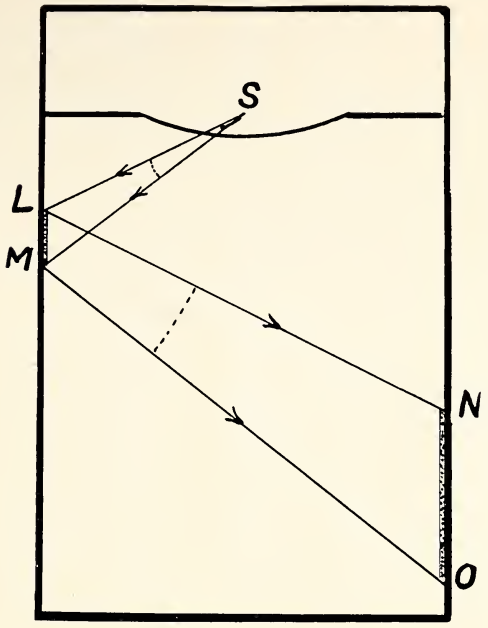


Fig. 1

(really a trifle more) than would covering the larger space N O of the second wall. The material required to cover the space N O and which would absorb but a small fraction of the total energy emitted by S would absorb all, or nearly all of it, if wound in the form of a tube surrounding S.

Consider another illustration. Suppose we place a sound absorbent over an open window. It would actually increase the reverberation in the room, as the material would reflect a portion of the sound which the uncovered window would transmit in toto.

It *does* make a difference where the sound absorbent is placed. Other things being equal, the material should always be placed over the portion of the wall or ceiling that has the lowest coefficient of absorption at the outset. However, even this rule has exceptions.

Let us suppose a theater with perfectly absorbing side walls, floor, ceiling and stage, but a hard plaster end wall opposite the stage. The reverberation period of such a room would be very small, much smaller than the one second limit given in paragraph (3). A speaker standing near the rear reflecting wall would notice no reverberation, as the time interval between his spoken word and its return to him by reflection from the near wall would be very short. Should he speak on the stage the sound wave would require time enough to travel twice the length of the room before reaching his ear the second time. This would produce a disagreeable echo—what is known as a sound "back slap." Some absorbing material on the far end wall of the room is absolutely necessary to remedy such a condition. Unless the reflection from the rear end of a room is broken by balconies or the equivalent, the wall should be partially or wholly

covered with acoustic absorbing material, the amount depending on other features of the room.

Space forbids a discussion of numerous other mistaken ideas, such, for instance, as the belief that a cone loud speaker has a sound directive effect; that troublesome reverberation in a large auditorium can be corrected by using several loud speakers installed in different parts of the room; that a few flags or a little bunting can materially improve bad acoustics; that baffle boards are resonators or that they should be covered with sound absorbing material, and so on. I shall consider but one of these mistaken ideas, the one having to do with horns, sounding boards, and other resonators. Such things do not function at all in the way they are quite generally supposed to function. Reference to figure 2 will illustrate the point. A would-be inventor has taken out a patent

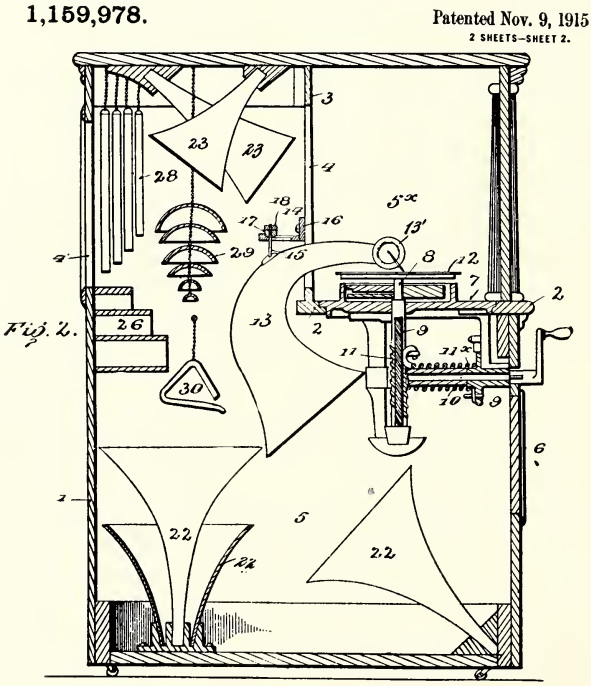


Fig. 2

on a phonograph with a case containing horns of various sizes, triangles, bells, chimes, and organ pipes. Another inventor, in addition to the above items, included a xylophone and harp in his design of a phonograph cabinet, evidently expecting each to reinforce by resonance the particular pitch and quality of sound that it would give if itself a sound source. Such things are powerless to affect sound quality or intensity in the slightest degree. It would be just as effective to put in the case a picture of a bull frog to reinforce the low notes of a bass singer. A piano sounding board is not thrown in vibration by the sound waves produced by the string, but by the vibrations communicated from the

string to the board through the wood and metal by which they are connected. A sounding board held in front of a vibrating string but not connected to it in any way, will *not* increase sound intensity. Indeed, it will reduce it.

The only reason a horn increases the intensity of the sound from a phonograph reproducer is that the reproducer diaphragm, being forced to vibrate inside a closed body of air, is made to *do more work* than if it vibrated in the open.

A baffle on a cone speaker increases sound intensity—not by vibration or resonance—but by preventing destructive interference of sound waves. Remembering that waves produced by the rear surface of the cone are always in opposite phase to those produced by the front surface, sound intensity can be increased by preventing their union while in opposition. A baffle should be reflecting, not absorbing. It should be rigid, not resonant. It should not be in contact with the loud speaker, either directly or indirectly.

Applying to the case of a theater with a resonant floor or side wall, no decrease in reverberation can be brought about by stiffening or fastening the vibrating member so it can not vibrate. No body can give out more energy than it absorbs. Should a side wall be thrown into vibration by sound waves falling upon it, the vibrations can not give out any more sound energy than was taken from the original sound in producing those vibrations. And since a vibrating wall produces as much sound on one side as on the other, half the energy absorbed in resonance is liberated outside the room. Thus the sound intensity inside the room is *diminished* rather than augmented by a resonating wall.

Much money and inventive effort would be saved if false ideas concerning sound phenomena were not so prevalent.

A NEW, EFFICIENT AND ECONOMICAL TYPE OF SOUND ABSORBING MATERIAL, AND A SIMPLE AND INEXPENSIVE METHOD OF INSTALLATION

Arthur L. Foley, Indiana University

My first detailed study of the problem of correcting faulty acoustics was in the year 1919 when I was asked to improve the hearing in the auditorium of the Student Building of Indiana University. Bids were taken from firms making a business of acoustic correction. As they ran much higher than the sum the University could allow for the purpose, I undertook the job myself and evolved an entirely new plan for the purpose. The scheme was described to the Indiana Academy of Science at the annual meeting in Indianapolis, Indiana, December, 1919, under the title "Correction of the Acoustics of the Auditorium of the Student Building of Indiana University" (P. 46, Proc. Ind. Acad. Sci., 1919). I did not submit the paper for publication, waiting to learn how well the installation would stand the test of time.

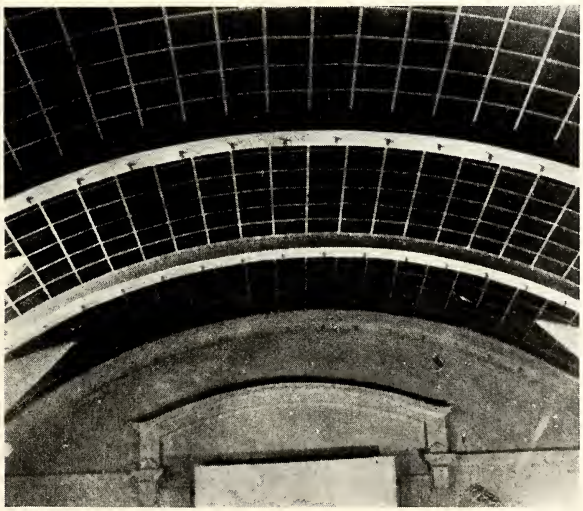


Fig. 1.

Figure 1 is a picture showing the barrel shaped ceiling which was chiefly responsible for the very unequal sound distribution and the all but impossible hearing in the room before correction. The picture shows the ceiling after correction. Imagine that, instead of the panels, the ceiling between the arched beams is plain plaster, and we have a picture of it before correction. Bidders had figured on covering the entire ceiling with sound absorbing material. I adopted an entirely different plan. I removed the wire lath and plastering

between the arched beams and in its place securely fastened wood strips or grounds to which was nailed screen wire. The distance between the grounds was such that the stips of screen wire were nailed along the edge only, each ground supporting the two wire strips on its sides. After the wire screen was in place the wire joints were hidden by nailing over them a wood strip or mold. Cross strips were used to give a panel effect. Behind the wire screen was placed the absorbing material, giving the finished appearance shown in the figure. The installation not only reduced the reverberation, but it completely eliminated the uneven sound distribution due to the condensing mirror effect of the barrel shaped plaster ceiling.

The reader may wonder why the plaster ceiling was removed, since the ground could have been fixed directly to it and the screen wire with absorbent behind it placed in position and paneled without removing the plaster. The plaster was removed to eliminate entirely its focussing effect, which could not have been done otherwise. The best absorbing material I could have placed behind the wire would have absorbed but fifty to sixty per cent of the sound energy falling upon it, leaving a third to half the sound to be reflected by the plaster wall behind the absorbent. Removing the plaster permitted the sound to pass into the attic where there were no concave sound mirrors, and where wood beams, rafters, sheathing, etc., by their absorption, greatly reduced the amount of material needed on the screen wire.

Another reason for removing the plaster was that the architectural effect of the projecting arched beams was not imparied by reducing that projection, as would have resulted had the ceiling between them been lowered by placing absorbing material under it.

I have recently filed an application for a patent on a method of applying sound absorbing material to any wall, ceiling, or other surface, a method essentially like that used in the Student Building years ago. Together with the Superintendent of the company manufacturing Balsam Wool sound absorbent, I have applied for a second patent, this one covering the facing of Balsam Wool with screen wire, the wire projecting a half inch beyond the edge of the wool for nailing to the wood ground.

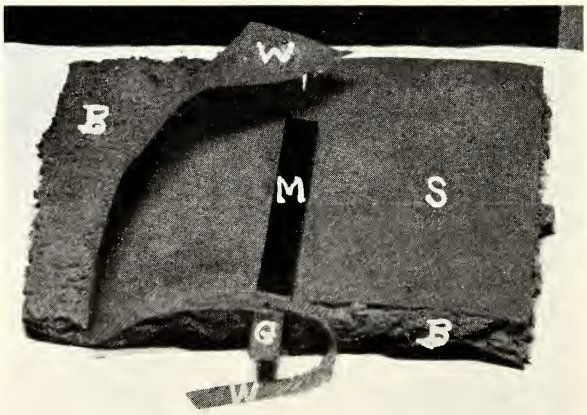


Fig 2

Figure 2 is a picture of a small piece of the material. S is the screen wire surface of the material as it appears when the observer is quite close to it. At a distance greater than eight or ten feet the mesh of the wire is practically invisible. W is a portion of the wire torn loose and folded back to show the fibrous (and porous) structure of the Balsam Wool B. P is the wire projecting beyond the edge of the wool. G is the ground to which the two pieces of absorber are nailed, and M is the mold to hide the wire joint and give a finished appearance to an installation. Note that the ground is of the same thickenss as the absorbing material.

Both patents have been assigned to the company which has been manufacturing cloth faced Balsam Wool for several years, and which is now marketing the wire faced product

The chief steps in the manufacturing process are as follows: Wood, largely waste from northern Minnesota saw mills, is shredded and treated chemically to make it vermin proof, and as nearly fire-proof as possible. After being sprayed with a water-proof adhesive the fiber itself is sprayed to a uniform thickness (usually an inch) on screen wire. Adhesive coated crepe or Kraft paper applied to the upper surface (the one opposite the screen wire) completes the job.

When weighing the merits and demerits of a sound absorbing material there are many points that should be considered. I shall mention some of the more important ones.

(1) An acoustic absorber should have a high absorption coefficient, and one as nearly uniform as possible for all common sound frequencies, or pitches.

The higher the absorption coefficient the smaller the amount of material required on any particular job, the smaller the expense of applying the material, and the better the chance of being able to apply it in the most convenient and otherwise desirable place. From our previous discussion of concave surfaces it is evident that such surfaces demand an absorbent having a high absorption coefficient.

If the absorption of an acoustic material is highly selective, it is efficient for sounds of certain pitches only. This results in a change in the quality of sounds reaching the ears of the audience.

The table below gives the absorption coefficients of Balsam Wool (determined by the writer) compared with the average coefficients of seven other advertised acoustic absorbents.

Absorption Coefficients

Frequency—Double Vibrations per second	128	256	512	1024	2048	4096
Absorption Coefficients of wire screen covered Balsam Wool	.09	.26	.48	.64	.55	.40
Average of the Absorption Coefficients of *seven* other advertised acoustic absorbers	.08	.21	.33	.47	.46	.38

(2) An acoustic absorber should be cheap, to buy and to install. However cheap the purchase price of an absorber may be, if it requires the services of expert or experienced men to apply it, its installation is necessarily expensive. It is evident that the method of application described in this paper is so simple that any carpenter, even a "saw and hatchet" carpenter, should be able to do the work satisfactorily. As a matter of fact, the total cost of acoustic correction

with screen wire faced absorbent as previously described should be from one-fifth to one-half the expense by other methods.

(3) Other things being equal, a light weight absorbing material has many points of superiority over a heavy material. Freight and drayage charges are less, the material can be handled more easily and threfore installed more economically, grounds for supporting the materials may be lighter and their attachment to walls and ceilings less secure, and no strengthening of wall or ceiling structure is necessary to carry the extra load of the applied absorbent.

Screen wire faced Balsam Wool weighs but 6.24 ounces per square foot, the lightest absorbent of which the author has any knowledge.

As an instance of the advantage of a very light weight material, I cite the the case of one Indianapolis theater in which there was a large duck awning over the central portion of the gallery in the rear. The upper surfaces of the ducking could not be seen from any part of the main floor or gallery. Upon my recommendation strips of Balsam Wool 30 inches wide and extending full length of the awning were laid over the ducking—no attachment was necessary. The wool was so light that it produced no perceptible sagging of the ducking. Three hundred square feet of absorber were thus applied.

(4) Reference to Figures 3 and 4 gives some idea of the fire resisting qualities of screen wire faced Balsam Wool.

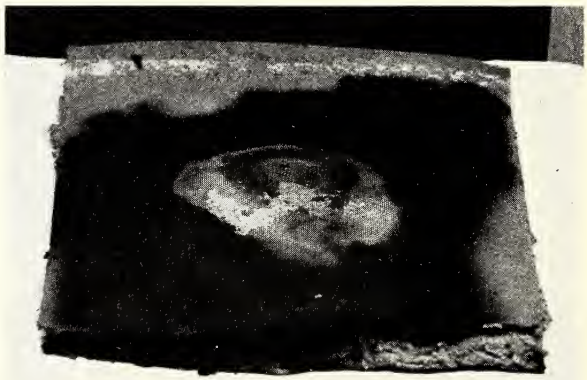


Fig. 3

Figure 3 is a photograph of a piece of wire faced Balsam Wool after being held in a horizontal position, wire screen surface below, directly in the flame of an alcohol burner with wick three inches in diameter. An alcohol flame was used instead of a gas flame to avoid a carbon deposit from the flame itself. The picture shows the blackening of the wire due to the charring of the Balsam Wool immediately behind it. When the wire was stripped off and the wool examined it was found that the charring did not extend to a depth of more than an eighth of an inch.

Figure 4 shows the result of subjecting a piece of screen wire faced Balsam Wool to the blue flame from a large blast burner designed for blowing glass. The absorbent was applied to a vertical wall and the horizontal blast directed

against the wire facing. In a second or two the wire facing became red hot (white hot near the center of the flame) over a space about five inches in diameter. At 45 seconds one of the wires burned in two and two or three more followed within five seconds. This occurred at the oxidizing tip of the blast. After five minutes the hole was but three-eighths inches in diameter—five wires burned in two. One minute after the blast was applied the flame passed through the hole in the screen and could be seen behind it. At the end of three minutes the wool had been carbonized through to the wall, and was emitting considerable smoke. Two minutes additional exposure increased the size of the cavity in the

Fig. 4

wool to a diameter of approximately seven inches. When the blast was removed the wool continued to smoke for some two minutes. There was no flame, but the thoroughly carbonized wood fiber was evidently burning where it had been directly in the path of the flame. The glow died out rapidly and was entirely gone within two minutes after the blast was removed.

The dark streak along the lower edge of the surface of the screen wire in figure 3 was produced by a white hot nichrome wire which was kept lying in contact with it for five minutes. The effect is confined chiefly to the end contacts. Between these points the screen wire carried a part of the current, the temperature of that portion of the nichrome wire being considerably reduced. Evidently the wire screen materially reduces fire hazards from overheated electric wires, as well as those arising from other causes.

OUTPUT CHARACTERISTICS OF MAGNETIC PICKUPS

J. B. Hershman, State Teachers College

The pickup is an electro magnetic device for transferring mechanical vebrations into electrical potentials. The most fundamental laws underlying this piece of apparatus are Faradays laws of induction and Rowlands law of the magnetic circuit that magnetic flux equals magnetomotive force divided by the reluctance.

The magnetic pickup is superior to mechanical reproducers for several reasons. Among these are: (a) At extremely high and low frequencies, amplifier characteristics can be made to compensate for loss in amplitude in recording. (b) Filters may be used to reduce "surface noise." (c) Any volume may be generated without distortion.

A pickup and its associated amplifiers and reproducers form a system such that falling characteristics in frequency in one part is compensated by a rising characteristic in another part. Thus the result is that almost any particular band of frequencies may be eliminated or augmented.

The mechanism of a magnetic pickup is very simple. It consists of a permanent magnet between the poles of which is some type of armature separated from the poles by a short air gap. The armature is movable and connected to the needle which is forced to vibrate by following the groove on a record. In a coil which surrounds the armature an induced voltage is generated. The flux through the armature is proportional to the reluctance, which in turn is varied by changing the length of the air gap.

The three fundamental equations for such a device being:

$$\phi = \frac{\text{M.M.F}}{\text{R}}. \tag{1}$$

Where ϕ is the flux, M.M.F the magnetomotive force, and R the reluctance.

$$\frac{d\phi}{dt} = \frac{kdx}{dt}. \tag{2}$$

Where x is the distance the armature moves in the air gap, and k is a constant depending upon the units used.

$$E = \frac{d\phi}{dt} = \frac{k\,dx}{dt}. \tag{3}$$

Where E is the voltage generated.

An ideal pickup should have a rising low frequency characteristic to make up for the loss in amplitude necessary in recording low frequencies. The voltage frequency curve should have no sharp peaks indicating resonance and consequent distortion. Such a device should have a rapidly falling characteristic above 5,000 cycles to prevent surface noise or "needle scratch."

The purpose of this paper is to outline a method for measureing the output voltage of a pick up at frequencies from 50-5,000 cycles and thereby obtain a voltage frequency characteristic over the ordinary acoustic range.

The ear cannot be relied upon in determining the points of maximum signal intensity because a great many people are relatively deaf to certain frequencies as indicated by the work of J. P. Minton[1]. Another important point to be considered is the sensitiveness of such a device, that is its actual output voltage. To measure this voltage a vacuum thermocouple was first used but due to the slow action of such a device the results obtained were unsatisfactory. A vacuum tube voltemeter of the "leaky grid" type was then constructed. This instrument was then calibrated in R. M. S. volts and used to measure the actual output voltages. A set of constant frequency records, which were made in the Bell Telephone laboratories, was obtained from the Victor Company. If rotated at the stated speed the grooves of these records were designed to give a constant frequency to a sound reproducers stylus at approximately constant energy output.

Since a pickup is a complex mechancial and electrical system both the mechanical and electrical impedances are effective in determining the output characteristics of such a device. Consequently the output voltages must be measured under conditions which are the same or similar to the conditions of actual use. Figure 1 shows three methods used for measuring the output under different conditions. In addition curves were taken with only the voltemeter as load, a condition which would exist were such a device to operate directly into a vacuum tube. In practice however such devices generally operate directly into an input transformer or a volume control device.

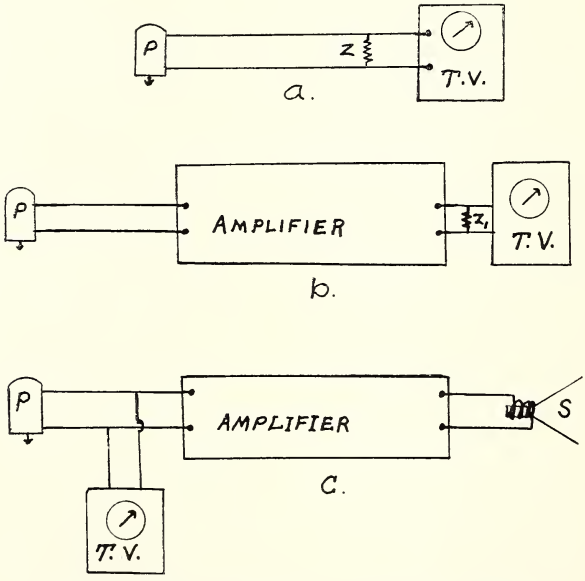


Fig. 1. Schematic diagram for tube Voltmeter connections

[1]Phys. Rev. XIX. No. 2, p. 80; 1921.

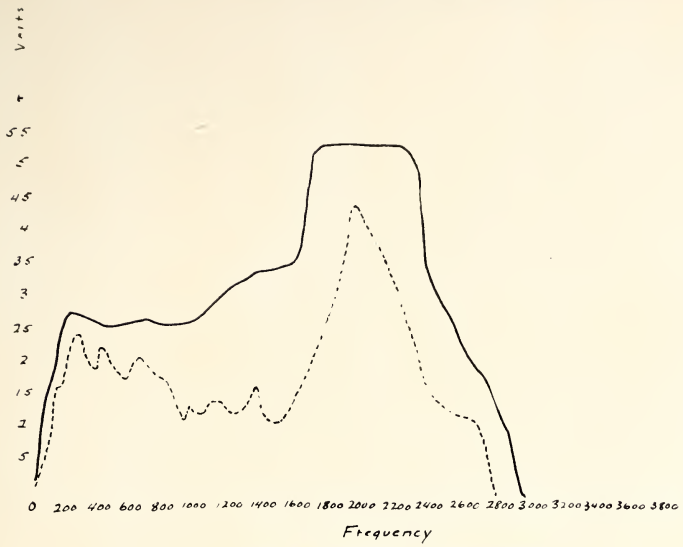


Fig. 2. The output of a poor pickup.

Figure 2 is a curve showing the output characteristics of a cheap pickup. For this curve the frequencies are plotted as abscissas against the voltages generated as ordinates. The continuous line gives the output when the device is operating directly into the proper amplifier. The broken line is the characteristic curve of the pickup with only the vacuum tube voltmeter as load. This pickup would over-emphasize the notes between 1,600 and 2,600 cycles and give practically no reponse above 3,000 cycles.

Figure 3 represents a higher quality pickup. The no load curve is very poor while the curve for proper load is excellent with the exception that the frequencies above 3,400 cycles do not register.

Figure 4 is a curve showing the characteristics of a good pickup. This pickup has a flat curve in which the lower frequencies are slightly augmented. It reproduces all frequencies up to 5,000. With a proper designed amplifier this device would give very faithful reproduction. The broken curves represent the generated voltages at loads other than the proper load. These curves show in some cases marked resonance peaks indicating distortion. It may be noticed that with the exception of the curve of figure 4 the cut-off frequencies are too low.

The accompanying curves were made by Geo. M. Urey in a study of the reasons for excessive record wear, with equipment designed and furnished by the author. Mr. Urey found by microscopic examination that the record grooves broke down at frequencies corresponding to pronounced peaks in the voltage output curve. Such peaks cause harsh metallic sound in the amplified sound output. These resonant peaks can be corrected by: (a) Mass loading in the mechanical system for low frequencies, (b) damping springs and cushions for the high frequencies, (c) matching impedances to prevent resonance and reflections in the electrical system.

Much research has been done upon pickups in the last two years and the device is at present a close competitor of the photo electric cell in sound reproduction. The problem of surface noise, however, remains to be solved.

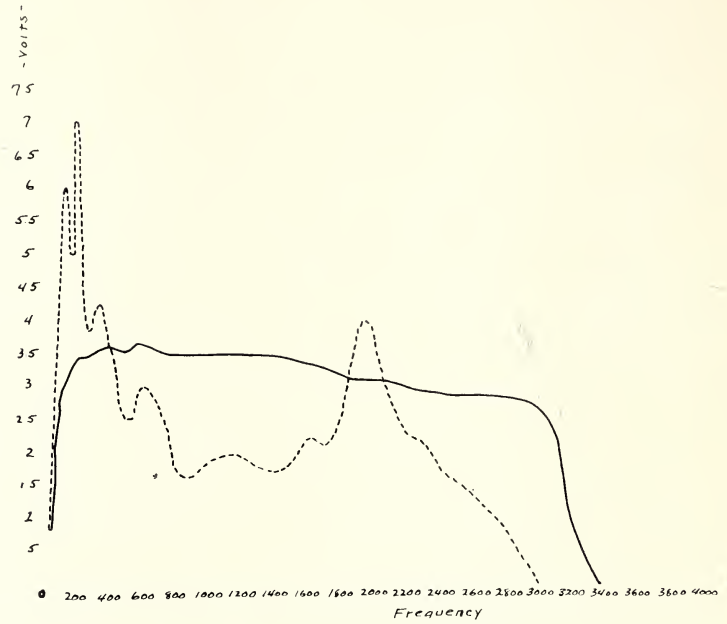


Fig. 3. The output characteristic of an average pickup.

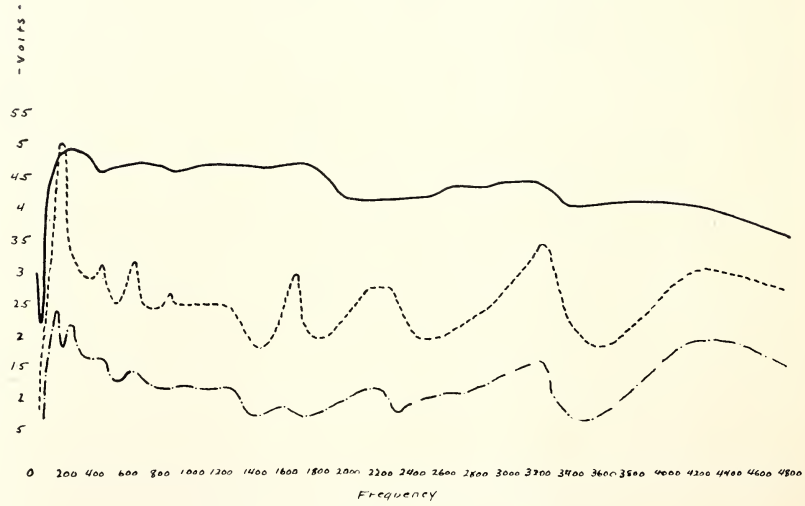


Fig. 4. The output characteristic of a good pickup.

RESISTANCE OF RADIO CONDENSERS

R. R. Ramsey, Indiana University

The resistance of air condensers has been measured by Weyl and Harris, Inst. Rad. Eng. 13, 109, (1925); by Callis, Phil. Mag. 1, 428, (1926); and Phys. Rev. 27, 113, (1926); by Brown, Weisbusch, and Colby, Phys. Rev. 29, 887, (1927); by Ramsey, Phil. Mag. 2, 1213, (1926); Phys. Rev. 27, 151, (1926); Proc. Ind. Acad. Sci. 36, 135, (1926); by Dye, Proc. Phys. Soc. London 40, 285, (1928); by Wilmotte, Jour. Sci. Instruments, 12, 369, (1928); by Morris, Phys. Rev. 33, 1076, (1929); and by Fletcher, Phil. Mag. 9, 464, (1930).

Before 1925 all measurements of condenser resistances at radio frequency were made by a comparison method in which a good condenser whose resistance was assumed to be zero was compared with the condenser in question. Certain measurements of condenser resistance made at frequencies of 3,000 cycles or less indicated that the resistance of a good condenser diminished as frequency increased and became practically zero at frequencies in the neighborhood of a million cycles if the same law held.

The method which Callis carried to completion in this laboratory was started in 1924. Although Weyl and Harris published their results early in 1925 Callis was not aware of it until late in the year after his paper had been sent for publication. These two sets of independent results with different methods gave results which agreed in that the values were very large compared to the usually accepted values which were supposed to be near zero. The results were of the order of one to ten ohms depending on capacity and frequency. These methods were alike in that they used a form of resistance-variation method with coils of relatively large inductance. Brown, Weibusch, and Colby used a resistance-variation method in which the coils used had very small inductance and obtained results much smaller than the observer mentioned above. One hundreth of an ohm being the order. Ramsey used Fleming's thermal method and obtained results in the neighborhood of a tenth ohm. Dye's method is an involved substitution method in which a specially constructed air condenser is used and the results are the values of the excess of the ordinary air condenser over that of the special air condenser. Detailed calculations show that the resistance of the special air condenser could be neglected. His results range from .011 ohm to .6 ohm.

The method used by B. D. Morris is much the same as that used by Ramsey except that instead of using the themal expansion of air as a means of indicating thermal equality in the two bulbs iron-advance thermocouples were used.

When thermal equilibrium is obtained we have $i^2R = I^2r$ where R is the resistance of a short piece of resistance wire; i, is the direct current flowing through the resistance, R; I, is the radio frequency current flowing in the condenser whose resistance is r.

The change in the method was made because there seemed to be a lag in temperature in the bulb containing the radio frequency circuit. The thermal junctions were used and they indicated the same lag while heating but also

showed the condenser in the radio frequency side apparently evolved heat for some time after the current had been shut off.

The results given here were all taken after the two bulbs had come to thermal equilibrium and had remained in equilibrium for some time. Measurements were made at frequencies ranging from that corresponding to 410 to 125 meters wave length, and with capacities ranging from .00001 microfarads to .00024 microfarads. The resistance obtained varied from .07 ohms for relatively short wave and large capacity to 11. ohms for relatively long wave and small capacity.

A comparison of these results indicate that the resistance of a radio frequency air condenser, to a fairly close approximation, is directly proportional to wave length and inversely proportional to the three halves power of the ratio of capacities. Using these imperical assumptions the resistance was calculated for standard conditions by the equation,

$$R_s = R(300/\lambda)(C/.001)^{3/2}.$$

The standard condition was taken as 300 meters wave length and .001 microfarad capacity. R_s is the resistance of a .001 microfarad air condenser when the current has a frequency corresponding to 300 meters wave length or one million cycles. The measured values and calculated results are shown in Table I. In this table it will be seen that R_s is nearly the same (the value being near .01

TABLE I. MORRIS'S RESULTS FOR THE RESISTANCE OF AIR CONDENSERS

$$R_s = R(300/\lambda)(C/.001)^{3/2}.$$

λ	C	R	R_s
125	.00001	5.5	.0132
280	.00001	11.0	.0122
190	.000054	.68	.0092
280	.000054	.79	.0106
320	.000054	.96	.011
280	.00013	.170	.0086
306	.00013	.195	.009
410	.00013	.275	.0095
290	.00024	.0706	.0086
325	.00024	.076	.0083
360	.00024	.079	.0078
400	.00024	.096	.0085
		Mean	.0098

ohm) although there is a small systematic variation of the values indicating the assumed law is not exact.

In Table II the same law has been applied to the results of other observers. It will be noted that the first three sets of results, all of which are resistance-variation methods, agree much better than is apparent from the original data. Weyl and Harris, and Callis's results were obtained with relatively large inductance while Brown, Weibusch, and Colby used very small inductance. The latter necessarily used short waves and large capacity making their results low compared to the first two observes. Ramsey's results were made with the thermal method. They are seen to agree with the results in Table I.

Table III shows the results of Dye. The results of Dye are smaller than any of the others. It will be remembered that his method is a substitution method in which a condenser of practically zero resistance was used.

TABLE II. RESISTANCE OF RADIO FREQUENCY CONDENSERS

Comparison of results taken from various sources.

The resistance is calculated for standard capacity and wavelength, i.e., 0.001 microfarads and 300 meters, by the equation

$$R_s = R(300/\lambda)(C/.001)^{3/2}.$$

	λ	C	R	R_s
Weyle and Harris	96	.0005	1.2	1.33
	96	.0001	2.8	.286
	96	.00005	18.5	.65
	200	.0005	.71	.37
	230	.0005	.86	.39
	260	.0005	1.04	.41
				Mean .57
Callis	300	.001	1.65	1.65
	300	.0005	2.8	.96
	300	.0001	10.65	.33
				Mean .98
Brown, Weibusch and Colby	43.4	.00048	.113	.26
	63	.00048	.15	.24
	83	.0018	.042	.38
	119	.0018	.049	.30
	119	.00386	.0284	.58
	172	.0038	.0305	.40
				Mean .35
Ramsey	27	.00008	.06	.015
	40	.00008	.04	.0068
	80	.00008	.06	.0051
	300	.00008	.098	.0022
				Mean .0098

Miss Fletcher in investigating the supposed "gas effect" discovered by Morris finds that the apparent effect is not due to an evolution or absorption of gas but that it is due to the fact that the source of heat in the condenser in the radio frequency circuit is inside the condenser while the source of heat is a wire outside the condenser in the comparison circuit.

This being true the inside of the condenser in the radio frequency circuit is at a higher temperature than the outside when the two circuits are in thermal equilibrium. When allowed to cool to the temperature of the room the cooling curves of the two bulbs will be different. This effect makes it appear that the

TABLE III. DYE'S RESULTS FOR THE RESISTANCE OF AIR CONDENSERS

$R_s = R(300/\lambda)(C/.001)^{3/2}$.

λ	C	R	R_s
* 200	.000184	.045	.0021
215	.000314	.024	.0060
300	.000494	.011	.00382
600	.000494	.014	.0026
790	.000184	.11	.0033
1200	.000314	.06	.0025
1500	.000494	.035	.0026
2150	.000184	.25	.00276
2610	.000314	.12	.0024
3000	.000494	.07	.0026
4600	.000184	.6	.0031
5000	.000314	.3	.0032
6000	.000494	.3	.0028
15000	.000494	.35	.0028
		Mean	.0033

*Note. This set of data is taken from points plotted logarithmically on unruled paper and are approximately the original observations.

radio frequency condenser heats slower and cools slower than the identical condenser in the comparison circuit.

In this investigation Miss Fletcher finds that some condensers obey the imperial law proposed by Morris and used above while the results obtained with other condenser give a more constant value for R_s, if the square root of the ration of capacities is used instead of the direct ratio in the formula.

When one remembers that the resistance of a condenser is made up of dielectric resistance which diminishes with frequency and of the resistance of connections and plates which can be called metallic resistance which increases with frequency it can be seen that the formula which applies to one condenser will not apply to a second condenser of different construction.

These formula give results for R_s which are near enough to a constant value to show that the resistance variation methods in which the resistance of the coil is calculated or liminated give results which are very large. It seems that there is an extra resistance in the circuit which in these methods is added to the resistance of the condenser. It has been suggested that this might be radiation resistance. Calculation of the radiation resistance from a coil shows that the added resistance is much larger than any reasonable value of radiation resistance. The heat methods give the resistance of the condenser much smaller showing that the energy dissipated into heat in the Condenser is relatively small.

To sum up, the resistance of a good radio Condenser is in the neighborhood of a few hundredths ohm and usually can be neglected when connected to the usual coil which has a resistance near ten ohms. If extreme accuracy is wished it is necessary to know the resistance at the exact frequency and capacity at which the condenser is used.

The fact that a certain condenser is measured and a low resistance is obtained does not necessarily mean that the resistance of this condenser is lower than that of a second condenser which has been measured and a large resistance obtained. Both condensers must be measured under the same conditions, wave length and capacity setting, or the results must be reduced to standard conditions.

The published results of Brown, Weisbusch and Colby indicate that the resistance of the condenser which they measured is very small. When these results are reduced to standard conditions they are about the same as those of Weyl and Harris and of Callis which were thought to be out of all reason. It might be well to point out that Brown et al used a Bureau of Standards type of condenser while the other observers used commercial condensers. Thus the commercial condensers measured had a resistance two or three times that of the Bureau of Standards type.

HIGH FREQUENCY RAYS IN THE AURORA BOREALIS AND HIGH ALTITUDE TESTS ON MT. EVEREST

E. A. Smith, Secaucus, New Jersey

In a previous paper delivered before the Indiana Academy of Science, a newly discovered penetrating radiation from the Aurora Borealis was discussed, which described experiments in the Hackensack River in Secaucus, New Jersey.

The present report briefly mentions new evidence found since 1927, which explains that these rays are extremely more energetic than first conceived. The data obtained from these experiments is now in preparation and will disclose valuable information of a startling nature. A series of experiments were carried out in Saranac Lake, Adirondack Mountains, N. Y., Lakes Ngantsi-Tso, and Kapur on Mt. Everest, N. Tibet, India and in Secaucus, New Jersey.

Previous data showed these rays capable of piercing nearly thirteen feet of pure solid lead before being stopped, while the latest evidence discloses values far in excess of what was formerly considered remarkable. The present paper explains what has been done in the way of advancing the study of this radiation.

Formerly experiments were conducted at the base of a concrete pipe shaft at a depth of 103 feet in the Hackensack River. In order to secure further information and confirm previous data, experiments were carried out in several other locations here and abroad, as above noted. The results obtained in these locations produced new evidence on the Aurora radiation at various altitudes. The data collected in Secaucus showed lower values than obtained in higher altitudes, which was naturally expected as the atmosphere in the mountains is much lighter. It was found that the atmospheric absorption coefficient for the Himalayan mountains is equivalent in absorbing power to about 19 feet of fresh water.

Penetrating Qualities of the Aurora Rays. In order to understand the penetration of these high frequency rays a few material substances are herewith mentioned which they are capable of piercing. Heretofore nothing was known or even realized regarding their existing power. The only previous known conditions about the Aurora was the visible streamers and the electro-magnetical disturbances set up in the atmosphere. These disturbances which we know about always cause interruptions in telephone, telegraph and power systems.

Several investigators in the past few years attempted to ascertain the principles of these rays but were misled by the various effects produced during polar storms. Evidence shows they even misjudged these powerful rays, of Cosmic origin. Their errors evidently were due to their using crude instruments which hampered the detection of these rays. To determine the qualities of these rays very sensitive instruments are essential and such have been used during recent investigations. Several well known investigators have approached the author to learn the characteristics of these specially designed instruments for their own benefit, but information has been withheld until the proper time.

It is known that substances which are transparent to some waves are opaque to others. What we call light is regarded as but a small part of a very long series

of electromagnetic waves in space. In order to measure the length of these waves the Angstrom unit is employed, whose length is one/one-hundred-millionth of a centimeter or, one/two-hundred-and-fifty-millionth of an inch. There are waves in space ranging from less than a thousandth of an Angstrom up to a length of many miles. The light waves are all included within a range of 3,900 to 7,600 Angstroms, or one/sixty-four-thousandth to one/thirty-three-thousandth of an inch. The longer of these waves makes the effect called red, and the shorter violet.

Glass is transparent to all of these waves. Ordinary glass is opaque to waves of less than about one/seventy-one-thousandth of an inch and more than one/eight-thousandth. Air becomes opaque to waves as short as one/one-hundred-forty-seven-thousandth of an inch, due to their ionizing effect upon it.

A thin sheet of ordinary metal will stop all the waves of the visible part of the spectrum, although a metal like pure gold may be made so thin that some of the light is transmitted. This shows that there is a certain degree of penetration of the light in the solid metal, so that it does not become altogether a perfect conductor to the rays. But there are in the quantum of electromagnetic radiation, waves other than those that appear as light, which are able to penetrate substances that to us seem opaque. Thus ebonite, an almost perfect insulator of electricity for ordinary purposes, though opaque to light waves, is transparent to all the longer waves beyond the red end of the spectrum. On the other side, waves shorter than light waves, such as the X-rays, readily pass through solids that are totally opaque to light. The recently discovered aurora rays coming upon us out of space are able to penetrate pure solid lead to greater depths with considerable ease. That only means that lead is transparent to them though opaque to light waves, and if we had eyes as sensitive to these aurora rays as they are to ordinary light, we could see through 20.8 feet of pure solid lead as through a window glass.

Here we have rays originating in the solar system, at least several hundred times more penetrating than X-rays. We can draw some fairly reliable conclusions as to the origin of these hard penetrating rays in the sun.

Observations and Measurements. Up to the present time, there has been in America only a general agreement in the measurements made on Aurora Rays by several physicists. For high altitudes up to 15,000 feet, Dr. Millikan claims he found a total discharge for an electroscope that was only one fourth of that calculated from the curves of Professors Kohlhorster and Hess for their previously assumed Cosmic Rays.

On Pike's Peak, Colorado, Millikan obtained a rate of production of ions seven times as large as that found by Dr. W. F. G. Swann on the same mountain. The variations are like those found, in the early determinations of e/m which showed fluctuations of about 100%. In our investigations of Aurora Rays in relation to altitude, direction, depth, geographical position and penetration in 1927 it was decided to develop more highly sensitive instruments. These new instruments have been used in all our latest experiments with satisfactory results and will be fully described in a separate paper in the future. However, eight sensitive electroscopes have been especially constructed for use under water at great depths. Their sensitiveness can be regulated by adjusting the atmospheric pressure within them. Furthermore their capacities can be determined with the greaterest of accuracy.

According to evidence obtained the penetrating qualities of Aurora Rays differ for different elevations. Another fact now established is that the Aurora

is always present and is the only possible source sending forth high frequency rays. When the Aurora Borealis is visible high readings are obtainable. On other days when the Aurora is invisible only normal readings are possible. These normal daily values have been mistaken by others for Cosmic Rays originating far beyond the Solar system.

In exploring different bodies of water, the rates of discharge of the electroscopes have been plotted against depth in equivalent feet of water beneath the top surface of the atmosphere. The readings fall upon a smooth ionization-depth curve which is being prepared for insertion in a future paper. This curve indicates a precison over a hundred times as great as that of Kohlhorster's and Millikan's instrument readings. Depth is reckoned in equivalent feet of water below the upper surface of the Earth's atmosphere.

The rate of production of ions diminishes as the electroscopes are lowered into the water. In previous experiments the readings ceased at a depth of 103 feet in the Hackensack river and 172 feet in Saranac lake. This means that our increased sensibility has proven the existence of considerably harder rays than we have previously observed. According to our latest measurements we have been furnished with reliable data that the Aurora Rays consist principally of at least three bands.

Experimental Locations and Results. In 1921 our first experiments were conducted in the Hackensack river and sounding balloons with special recording electrometers were sent up to an elevation of 15½ miles. The instruments testified to the correctness of the increasing discharge rate for all high altitudes, while the Aurora was semi-brilliant. In 1923, Kohlhorster from his experiments on the shielding power of the Alpine glaciers deduced an absorption coefficient of 0.25 per meter of water. It was finally concluded that rays of a powerful nature existed which must be more penetrating than those found by Kohlhorster. The results obtained in 1923 confirmed this and of course their existence appeared certain to be of Solar origin. The highest values of these rays were always observed during extreme intensities of the Aurora Borealis. This was verified by sinking sealed electroscopes in a concrete pipe shaft in the Hackensack river, Secaucus, N. J. and at Saranac lake, Adirondack mountains, N. Y., a distance of 350 miles at approximately the same time and dates. Telephone communications were arranged for between these two points during daily investigations However, we found different readings at both places. In the Hackensack river the ionization at the surface was 2.3 ions while at Saranac lake, altitude 5,000 feet we observed 12.7 ions per c.c. per sec. As the electroscopes were lowered into Saranac lake the number of ions diminished gradually to 2.3 ions at a depth of 172 feet. Below this level no further decrease was noted. The two sets of observations otherwise agreed in every respect. The additional 5,000 feet of air through which this radiation had to pass from the level of Saranac lake to the surface of the Hackensack river was in theory equivalent in absorbing power to 6.5 feet of fresh water. Here it was maintained that the rays in question had a stronger penetrating power at the higher altitude than at sea level. The evidence shows that the Aurora Rays varied in intensities at both places of observation. In 1927-28 and the first half of 1929 further experiments were carried out in Lake Ngantsi-Tso, elevation 15,745 feet and in Lake Kapur, elevation 22,230 feet, in the vicinity of Mt. Everest. The results found at both altitudes showed the extreme possibility of the production of a new type of ray of which nothing before was ever known. These same type of penetrating

rays appeared every day and night and reached their maximum values during the brilliant Aurora displays. In 1928, four additional highly sensitive lead sealed electroscopes were used at Mt. Everest, which were specially designed for this purpose. A total of 12 instruments were used and there was good agreement in the ionization results obtained. In our investigations in Lake Ngantsi-Tso the electroscopes reached a steady state of ionization when 78.1 feet below the water surface and all contined to indicate a reduction of ionization until a depth of 209 feet was attained. In considering the atmospheric absorption above the lakes as shown in the accompanying table, our latest experiments reveal powerful rays so penetrating as to pass through more than 20 feet of pure solid lead before being fully absorbed. This evidently shows that the absorption indicated the presence in radiation of wave lengths from 0.00057 to 0.000029 A.

These hard rays come in independently of ultra-violet radiation from the Sun which under the influence of the Earth's magnetic field are diverted to the polar regions and there, their energy is scattered to the atmosphere and by a natural process converted into Auroral light.

TABLE

Location	Altitude—Feet	Ions per C.C./Sec.	Depths in Feet
Hackensack River	Sea-Level	2.3.....1.3	3.5.....125.5
Saranac Lake	5,000	12.7.....2.3	3.5.....172.
Lake Ngantsi-Tso	15,745	24.3.....3.7	3.5.....209.
Lake Kapur	22,230	38.4.....3.1	3.5.....910.

Atmospheric Absorption Coefficient at Places Given			
Hackensack River 28.0 ft.	Saranac Lake 22.5 ft.	Lake Ngantsi-Tso 19.7 ft.	Lake Kapur 18.2 ft.

Visibility of Auroral Displays. The Aurora is clearly visible in the Northern and Southern hemispheres near the poles. A few facts that are known is that their brilliancy occurs in high latitudes. At the Equator none at all are ever seen. In California, lower Florida and at corresponding latitudes in Europe and lower Asia there is on the average only one Aurora display visible every 11 years. In Canada and the Northern American States they are one hundred and twenty-five times as frequent while in British Columbia, Norway, and on Mt. Everest they have their most frequent occurrence. They are more frequent and brilliant in some years than in others, occurring mostly in Spring and Autumn.

High Altitude Tests. The lakes chosen as quite suitable for under water observations were Lake Ngantsi-Tso and Lake Kapur situated about 200 and

110 miles from the summit of Mt. Everest. Lake Ngantsi-Tso is about 210 feet deep lying at an altitude of 15,745 feet. It is about 900 feet in width and 2,100 feet long. Lake Kapur is about 917 feet deep lying at an altitude of 22,230 feet. It is about 600 feet wide and 1,700 feet long, and is surrounded on all sides by mountains. Lake Ngantsi-Tso was fairly shielded by mountains from any possible rays generated in thunder-clouds. The zero reading of the first four electroscopes in Lake Ngantsi-Tso corresponded to depths of immersion of 209 feet, which were 26.1 for electroscope 1; 24.3 for electroscope 2; 24.7 for electroscope 3 and 24.2 for electroscope 4. In several other tests our first four electroscopes produced similar readings. In order to obtain precision of a higher degree on the first four electroscopes we used two of our later designed electroscopes 9 and 10, which are very sensitive and found an increase in reading of two per cent. This required six electroscopes to obtain a final reading for confirming our previous values as well as the recent with the first four electroscopes. In Lake Kapur, which is 6,485 feet higher in elevation than Lake Ngantsi-Tso, we observed higher readings as usual during visible Aurora displays and in daily normal ionization. Here we found the readings of six electroscopes corresponding to depths of immersion of more than 909 feet, which were 37.7 for electroscope 1; 38.2 for electroscope 2; 38.4 for electroscope 3; 38.7 for electroscope 4; 38.5 for electroscope 5; and 39.1 for electroscope 6. A similar check was made on our tests in Lake Kapur as in Lake Ngantsi-Tso which agreed in every respect during the strong Auroral displays. The scale of readings were observed to increase about 24 hours before the peak of the storm arrived. When the peak arrived which continued for periods of about 35 minutes to 90 minutes the instruments reached their maximum readings. After the peak, our instrument readings showed a gradual decline for a period of 29 hours, when the storm subsided. We, however, noted fluctuations in the instruments for several days after which the ionization reached a low steady value. These values ranged from 8.7 ions for Lake Ngantsi-Tso and 14.6 for Lake Kapur.

Ionization at Sea-Level. With all our latest investigations it has been confirmed that normal Aurora radiation is always present. Sea-level and deep valley observations taken during thunderstorms showed no influence upon the electroscopes. A specially designed radiometer, however, showed slight fluctuations due to pulsations from lightning discharges. The ionization found at sea-level under all weather conditions was 1.7 to 2.6 ions per c.c./sec. A series of readings were taken on board ship from New York City to Cherbourg. The mean of seven readings taken under uniform weather and the normal daily ionization conditions with two electroscopes was about five ions.

Influence of the Milky Way on Aurora Rays. Since strong evidence on this point would have the most important bearing upon the Auroral Rays, we selected a fairly deep ridge near Lake Ngantsi-Tso. This ridge which was screened by the surrounding mountains, avoided any possible influences from the Milky Way during a consecutively twelve day investigation. Here we obtained a value of 19.3 ions at the bottom of the ridge. This value which is less than that obtained at Lake Ngantsi-Tso was probably due to the lower altitude. The elevation at the base of the narrow ridge is about 1,418 feet below Lake Ngantsi-Tso. This reading was taken during an Auroral display while at the same time other experiments were under way at Lake Ngantsi-Tso. About four

days later our readings in the ridge were reduced from 19.3 to 7.6 ions. This reduction again showed that the Aurora is responsible for the higher values found at other places of observation. We also found no changes in our readings when the Milky Way was over head or out of sight. This is in agreement with our preceding measurements, and also with recent careful research at sea-level done subsequently to this by Drs. Hoffmann and Gockel. All past investigations were conducted under favorable conditions as to altitude and temperature constancy. The resultant data from our balloon surveys is not ready for full discussion at the present time, but will be presented in our next paper. Further experiments are now under way, in another lake on Mt. Everest, which is about 75 miles N. E. of Lake Kapur. This lake is situated at a higher altitude, and so far as known is the highest lake in the world. By exploring this lake, several advantages may be realized and new evidence revealed. Investigations are being made by pilot balloons, by aeroplane and by experiments in this lake.

Conclusions. We have found our latest readings in Europe for similar altitudes to agree very closely with observations in America. The readings taken at Mt. Everest show increased ionization due to the high altitudes. Our twelve electroscopes possessing different forms and material agreed in giving at sea-level an ionization value of 1.7 to 2.6 ions. On the Atlantic ocean our mean readings were five ions. A continual series of readings taken for twelve consecutive days in a deep valley failed to produce any difference between the Aurora radiation coming into the Earth when the Milky Way was overhead or when out of sight. Observations made during thunderstorms at sea-level showed no differences on the Aurora Ray readings. All our electroscopes showed a corresponding increase in their readings when the Aurora was visible, and very low values after the Aurora storm subsided. These low readings continued as normal on other days when the Aurora was not visible. The corresponding wave lengths were carefully determined according to Compton's and Dirac's equations and are 0.00057 to 0.000029 A.

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INSECTS OF INDIANA FOR 1929

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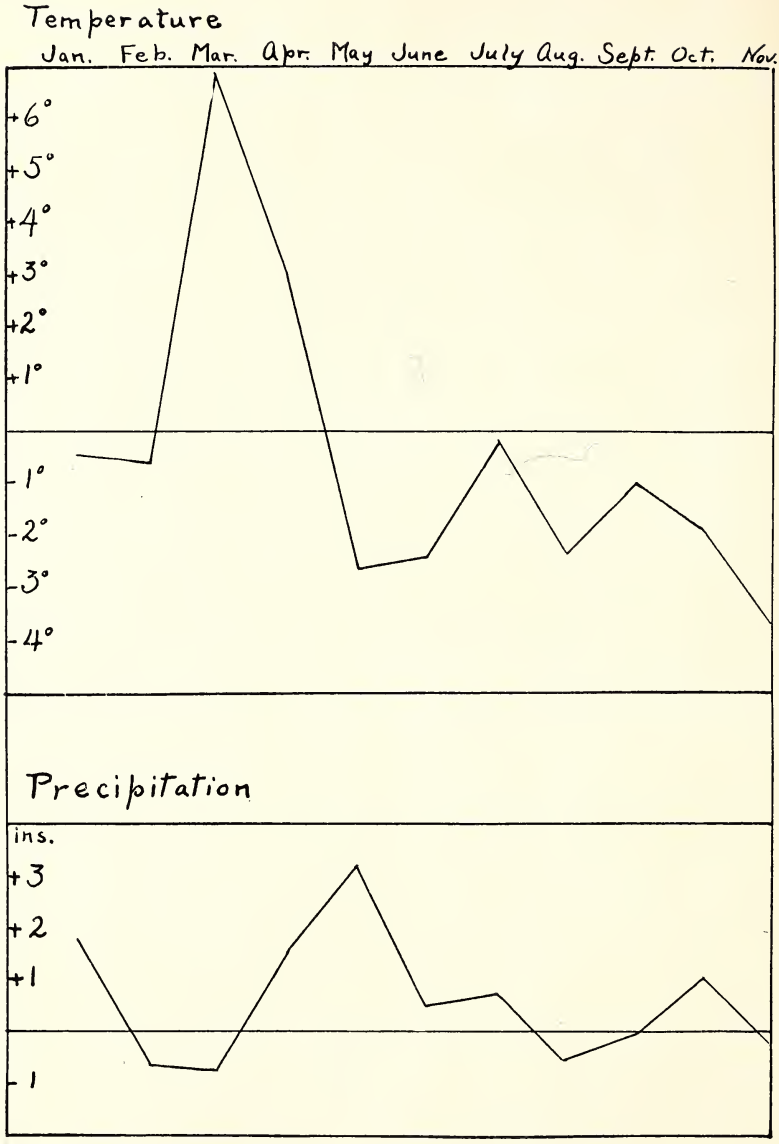
The following account is a summary of the more important insect problems of the past year (1929). The first annual account of the insect problems of the year was published in the Proceeding's of 1925. These annual records have been reported each year and it is anticipated that they will have a future value in determining the factors governing insect troubles and provide material for the prediction of insect troubles in years to come.

Weather Conditions. The temperature was below normal during January and February, although nearly 7°F. above normal for March, while the precipitation during these three months was approximately normal. April was one of the warmest and wettest on record, although the excess in temperature was during the first half of the month, the last half being normal or below normal. May was continuously below normal until the close of the month and the rainfall was nearly double the normal precipitation for that month. June to October was near normal in temperature and precipitation although, in general, below normal throughout the period in temperature. (See Table I and figure 1.)

TABLE I. COMPARATIVE MONTHLY WEATHER DATA FOR INDIANA, 1929

MONTH	Temperature		Precipitation		Number of days		
	State Mean	Departure from Normal	State Average	Departure from Normal	Clear	Partly Cloudy	Cloudy
	°F.	°F.	Ins.	Ins.			
Normal..	28.6		3.05				
January, 1929.....	25.0	−3.6	4.92	+1.87	9	7	15
Normal..	29.6		2.54				
February, 1929.....	25.1	−4.5	1.88	−0.66	10	8	10
Normal..	40.7		3.86				
March, 1929.....	47.6	+6.9	3.11	−0.75	11	10	10
Normal..	52.0		3.49				
April, 1929.....	54.9	+2.9	5.02	+1.53	12	8	10
Normal..	62.2		4.01				
May, 1929.....	59.6	−2.6	7.23	+3.22	12	9	10
Normal..	71.6		3.83				
June, 1929.....	68.8	−2.2	4.38	+0.55	16	9	5
Normal..	75.3		3.40				
July, 1929.....	75.1	−0.2	4.22	+0.82	16	10	5
Normal..	73.3		3.31				
August, 1929.....	71.2	−2.1	2.76	−0.55	18	8	5
Normal..	67.0		3.12				
September, 1929.....	66.1	−0.9	3.05	−0.07	14	8	8
Normal..	54.5		2.69				
October, 1929.....	52.7	−1.8	3.83	+1.14	14	5	12
Normal..	42.2		3.09				
November, 1929.....	38.6	−3.6	2.71	−0.38	11	5	14

*The writer is indebted to R. F. Sazama, W. P. Yetter, C. M. Packard, H. K. Riley, and L. F. Steiner for records.



CEREAL AND FORAGE INSECTS

Grasshoppers not abundant generally but reports from Sullivan and adjoining counties show abundance of these insects and considerable damage, especially to clover. The clover seed yield was apparently materially reduced because of grasshopper injury.

May beetles (*Lachnosterna* spp.) were out at Lafayette April 6 and 7 which is an unusually early record. May beetles were generally abundant in northwestern Indiana and there is evidence of an abundance of white grubs next year. Tiphia cocoons were observed abundant behind the plow at Windfall, May 15, indicating abundance of grubs last year and a high degree of parasitism. Hedge was damaged at Attica, September 19, by white grubs according to a report received.

Wireworms (Elateridae) were moderately abundant in low areas throughout the state, in some cases corn being seriously damaged.

Hessian fly (*Phytophaga destructor* Say). The following information has been furnished by C. M. Packard: "Much injury to the 1929 wheat crop by the Hessian fly occurred in southern Indiana. The spring of 1929 was rather favorable for early and continual fly activity in that part of the state. Abundant rainfall and favorable growing conditions, however, enabled many fields to outgrow fly injury and produce fair yields. In the central and northern parts of the state, fly injury last spring was slight as a result of the scarcity of fly the previous fall and the comparatively unfavorable weather for its multiplication during the spring.

"The summer prospect for infestation of wheat sown in the fall of 1929 was threatening in the southern half of Indiana. The stubbles contained large numbers of spring brood puparia and although parasitism was heavy in that area the percentage of puparia surviving the summer was sufficient to produce a serious outbreak, given favorable weather. In the northern half of the state a general scarcity of puparia in the stubble indicated light infestation this fall.

"The extended late summer drought was unfavorable not only to growth of volunteer wheat and fall fly pupation, but also to early preparation for sowing of wheat. As a result most of the wheat throughout the state was comparatively late sown and contains very little fall infestation. In southwestern Indiana, some localities received sufficient rain in late August so that considerable early preparation of the ground and sowing was accomplished. Abundant early September rains in this region also made possible further comparatively early sowings. These same rains caused general pupation and prompt emergence of flies, resulting in rather heavy fall infestations in volunteer wheat and early sowings from Attica south to the Ohio River. A few fields were sown early and received considerable infestation in the northern part of the state where local rains made it possible. When fly emergence occurred to any extent it was practically over well in advance of the recommended safe-sowing date. This fact, combined with the general delay in seeding caused by lack of moisture, served to mitigate to a large degree the severity of the infestation developing this fall. There is less likelihood of severe fly injury to the current crop then there was last year."

Chinch bug (*Blissus leucopterus* Say) was not observed during the year.

Neither the fall army worm (*Laphygma frugiperda* S. and A.) nor the common army worm (*Cirphis unipuncta* Haw.) were observed during the season, excepting one reported damage to corn by the latter at Greensburg, June 10.

The European corn borer (*Pyrausta nubilalis* Hbn.) continued to spread across the state and to increase in abundance in the older infested areas. In 1928 a total of 21 counties were found to be infested. At the end of 1929 eight additional counties were found infested making a total of 29 infested counties

in the northeastern third of the state. The counties infested by year beginning with the first appearance of the corn borer in Indiana are as follows:

1926	1927	1928	1929
Allen	Adams	Delaware	Blackford
Dekalb	Elkhart	Grant	Henry
Lagrange	Huntington	Fulton	Howard
Noble	Jay	Laporte	Madison
Steuben	Koscuisko	Starke	Miami
Whitley	Marshall		Porter
	Randolph		Union
	St. Joseph		Wayne
	Wabash		
	Wells		

According to counts made by federal investigators under the direction of D. J. Caffrey, the average infestation in the six counties first found infested in 1926 increased from .20 per cent in 1928 to .85 per cent in 1929. In Dekalb and Steuben counties the borers are now sufficiently common to be found by the average farmer. At the present rate of increase they should be sufficiently abundant in these counties by 1931 to begin to show noticeable injury. Not only have the numbers increased in the older infested areas but the spread south and west has been conspicuous. The large increase and spread can be accounted for in part by the fact that little or no attempt was made to properly plow under or otherwise dispose of corn stalks and stubbles and in part by the weather conditions which were favorable for the development and spread of the borer.

A number of European parasites of the corn borer were liberated in Dekalb and Steuben counties in 1929, by federal investigators. One species (*Masicera senilis*), a fly parasite, showed up exceptionally well for the first season. A total of 722 specimens of this parasite were liberated at a point in Steuben County. Recovery studies this fall showed a parsitism of 33 per cent in fields adjacent to the point of liberation and 20 per cent one and one-half miles away.

The common stalk borer (*Papaipenia nitela* Gn.) was generally abundant, the first reports being received June 1. Reports of injury were continuous until September 4, although most of them were received during June and July. Localities included in reports and observation included the following counties: Benton, Boone, Carroll, Cass, Clinton, Daviess, Dearborn, Delaware, Fountain, Grant, Jasper, Jennings, Johnson, Kosciusko, Lake, Lawrence, Marion, Marshall, Montgomery, Pike, Posey, St. Joseph, Sullivan, Tippecanoe, Tipton, Vermilllion, Vigo, Wabash, Washington, White, and Whitley. The majority of these reports referred to injury to corn. In one case a seven-acre field was practically destroyed. Injury to tomatoes was frequently reported and in one instance 20 per cent of a four-acre field was destroyed. In addition, the following crops were reported as being damaged: sweet potato, mango, dahlia, marigold, hollyhock, Gaillardia, Delphinium, Florida fern, cosmos, canna, Zinnia, lily, salvia, columbine, and snapdragon. Two reports were received from Mitchell and Newtown, respectively, of conspicuous injury to peach twigs in orchards of young trees.

Corn earworm (*Heliothis obsoleta* Fab.) continued somewhat scarce, but was more prevalent and destructive than in 1928.

Billbugs (*Sphenophorus* spp.) were not as destructive as during the past few years.

Webworms (*Crambidae*) were reported destructive to corn early in June at Manila, Columbus and Osgood.

Diatrea zeacolella Dyar and *Crambus* sp. (C. Heinrich det.) was reported as destroying 20 acres of corn at Howe, June 25.

A black flea beetle damaged corn at Camelton, June 24, and a black and also a striped flea beetle seriously injured corn at Connersville, June 25. A flea-beetle larva (probably *Systena frontalis* Fabr.) was numerous in Wabash River bottom lands of Gibson County, burrowing in corn seeds and seedlings, according to C. M. Packard.

Tipulid larvae (Tipulidae) were reported abundant in a timothy field at English, March 20. No damage was reported.

Overflow worm (*Agrotis ypsilon* Rott.) destroyed early plantings of corn on several hundred acres following late overflows on Wabash River bottom lands in Gibson County, according to C. M. Packard.

Granulated cutworm (*Feltia annexa* Tr.) damaged corn near Rensselaer in late June.

Corn root aphid (*Aphis maidiradicis* Forbes) was destructive to corn at Charlestown the last of July.

Southern corn root worm (*Diabrotica longicornis* Say) caused corn to fall at Newport, August 7.

Clover root worm (*Colaspis brunnea* Fabr.) damaged corn at Salem, July 13. The beetles were reported abundant and feeding on corn foliage at New Albany and English, July 8 and 12, respectively.

Cowpea aphid (*Aphis medicaginis* Koch) was abundant and destructive to cowpeas at Thayer, Aug. 20.

Larvae of the southern corn root worm (*Diabrotica 12-punctata* Fabr.) were reported burrowing in corn seeds and seedlings in the Wabash River bottom lands of Gibson County, according to C. M. Packard.

Jointworm (*Harmolita tritici* Fitch) was scarce throughout most of the state although common but not injuriously abundant in Gibson and Posey counties, according to C. M. Packard.

Mint flea beetle, (*Longitarsus memthaphagus* Gent.) damaged spearmint at Shipshewana, according to a report received September 9.

VEGETABLE INSECTS

Cabbage worms (*Pontia rapae* L.) were reported destructive to cabbage during June, July and August at Indianapolis, Greenfield, Dyer, Peru and North Judson.

Cabbage aphid (*Brevicoryne brassicae* L.) reported abundant on cabbage at Bristol, July 11.

Turnip aphid (*Aphis pseudobrassicae* Davis) was destructive to turnips at Lyons and Winslow during late August and early September. Heavy loss to a 15 acre turnip field was reported from Fort Wayne.

The cabbage and radish maggot (*Hylemyia brassicae* Bouche) reported during the spring as destructive to radish the season before (1928) at Frankfort, Medaryville, Nappanee, Pierceton, and Wolcott.

Onion maggot, (*Hylemyia antiqua* Meig.) reported damaging onions at Culver, Knox, Helmer, Shelby, Albin, Nappanee, Pierceton, Hudson, Medaryville, Warsaw, Hibbard and Winimac the last of July. However, reports and observations to date show decidedly less trouble than in 1928.

Striped cucumber beetle, (*Diabrotica vittata* Fabr) was reported destructive the last of June and early July at Georgetown, Galveston, Oakland City, Dublin, Newport, Seymour, Hagerstown, North Manchester, Lafayette, Lakeville and Sunman. Larvae were reported attaching roots of cucumber at Crawfordsville, July 1.

Melon aphis, (*Aphis gossypii* Glov.) reported during August as destructive at North Salem, Thayer, North Judson, Seymour, and Macy.

The pickle worm (*Diaphania nitidalis* Stall) was very destructive to pickles during July in Dearborn County.

Potato leaf-hopper (*Empoasca fabae* Harv.) was normally abundant and destructive in northern Indiana.

Flea beetles (species not determined) reported attacking tomatoes at Fremont June 6.

Tomato worms (*Phlegethontius quinguemaculata* Haw.) were very abundant at Lakeville, early in August.

Black blister beetle (*Epicauta pennsylvanica* DeG.) damaged cabbage, tomatoes, beans, and other garden plants at Mt. Liberty, August 15.

Chalcodermus aeneus Boh. injured beans at Campbellsburg, June 24.

Mexican bean beetle (*Epilachna corrupta* Muls.) was normally destructive in the southern half of the state. It was observed in Knox county, the farthest west in the state. It was also recorded from Warsaw but not destructive.

Asparagus beetle (*Crioceris asparagi* L.) reported destructive at Rossville, Aug. 12.

Rhubarb curculio (*Lixus concavus* Say) damaged rhubarb at Ft. Wayne in 1928.

Parsnip webworm (*Depressaria heraclina* DeG.) was a pest of parsnips grown for seed at Rensselaer in 1928.

Tortoise beetle larvae (*Cassidae*) were reported attacking sweet potato at Shoals, July 15.

Squash bug (*Anasa tristis* DeG.) was abundant at Lyons early in July.

Mole crickets (*Gryllotalpa hexadactyla* Perty) reported abundant and attacking planted tomato seed at Greencastle, April 20. This insect was also reported from Liberty and Brownstown in August but no report of injury.

Millipeds were reported damaging plants in several localities. From Berne, April 16, is the report they were abundant in gardens and that tomatoes and strawberries lying on the ground were eaten in 1928. From Jasper is a report, March 13, that they ate the roots of vegetables, flower garden and hot bed plants and it was specifically stated that they ate the roots of tomato and lettuce plants. From Huntington came the report (April 24) that these animals were eating the roots of various garden plants. During the summer radishes were injured at Logansport.

FRUIT INSECTS

The outstanding fruit pest in Indiana in 1929 was the Oriental fruit worm. In addition to the localities observed infested last year, the insect was definitely recorded from Anderson, Bedford, Terre Haute, North Vernon, Lafayette,

Anderson and Goshen. Apparently this new pest is now generally distributed throughout Indiana.

The following table shows the approximate dates of the important periods in the life cycle as observed at Vincinnes in 1929 by Sazama, Yetter and Steiner.

Brood	First Larvae	Peak of Larval Hatch	First Adults
Spring	.....	.....	Mar. 25
First	April 30	May 23	June 1
Second	June 10	June 25	July 8
Third	July 15	July 26	Aug. 8
Fourth	Aug. 15	Aug. 24	Sept. 3
Fifth	Sept. 9	Sept. 20	.....

The first twig injury was observed at Vincennes May 3 although not observed at Mitchell until late June, due no doubt to the scarcity of the insects in that region early in the season. The first fruit injury was noticed at Vincennes the last of June. By the middle of August the peach twigs had sufficiently hardened to make them unacceptible to the larvae and practically all of the larvae were entering peaches, which was during the Elberta and Hale harvest. At the present time over-wintering larvae are numerous in southern Indiana and in some orchards the parasitism exceeds 35 per cent. Four or more different species of parasites have been reared but they have not yet been identified.

In New Jersey, *Macrocentrus ancylivora*, a parasite of the strawberry leaf-roller (*Ancylis comptana* Froh.), has gone over to the Oriental fruit worm and is parasistising as high as 65 per cent of the worms. In as much as we had never found this parasite in Indiana, the writer collected several thousand infested twigs near Moorestown, N. J., late in May. From this collection over 500 adult *Macrocentrus ancyliovora* were reared. These were released in an orchard near Vincennes and counts made by Steiner at weekly intervals showed that it reached a maximum of 58 per cent parasitism 400 feet southwest of the point of release and 43 per cent 1,000 feet southwest of the area of introduction. The results are decidly favorable and indicate the possible future value of the natural enemies in controlling the fruit worm.

The experiments by W. P. Yetter with attractive baits also show great promise and possible value as a practical control.

The codling moth (*Carpocapsa pomonella* L.) was more abundant in 1929 than the year before and the second and third brood larvae were very abundant and caused considerable damage. Large numbers are over-wintering and indicate a serious situation for 1930. According to L. F. Steiner the first adults were observed at Bedford as follows:

Brood	Fruit Egg	First Larva	First Adults
Spring	.....	.....	April 27
First	April 30	May 20	June 30
Second	July 3	July 10	Aug. 15
Third	Aug. 17	Aug. 25	.....

The first adults appeared two weeks earlier than 1928 and a week earlier than in 1927. The peak of the first adult emergence passed before the first eggs hatched but cool weather, about that time, lengthened the hatching period. Second brood larvae began hatching about a week earlier than normal. At the present time the overwintering larvae are abundant.

Peach tree borer (*Aegeria exitiosa* Say) reported destructive at Indianapolis, Peru and Royal Center during September. In general no trouble is experienced from this pest where the paradichlorobenzene treatment is a regular practice.

Shot hole borer (*Scolytus rugulosus* Ratz.) was destructive to plum and peach at Anderson, Gary and Indianapolis during the summer.

The San Jose scale (*Aspidiotus perniciosus* Comst.) is being held in check in most commercial orchards. It was reported abundant on hawthorns at Liberty and on peach at Milltown during August.

Plum curculio (*Conotrachelus nenuphar* Hbst.) is a constant problem and is increasing in some localities in southern Indiana. It would appear that an earlier cover spray, one week after the petal fall, will be necessary in localities where curculio persists.

Apple maggot (*Rhagoletis pomonella* Walsh) (fig. 2) was very abundant and destructive to apples in Elkhart and Lagrange counties.

Bagworm (*Thyridopteryx ephemeraeformis* Haw.) defoliated plum at Brazil and Brookville, apple at Vincennes and fruit trees in general at Worthington during July. These were unsprayed orchards. At Evansville they were abundant in shade trees in July.

Strigoderma arboricola Fabr. adults were reported abundant in an orchard near Michigan City, June 24, but no statement of damage was received.

Woolly apple aphid (*Eriosoma lanigera* Haas.) was abundant on apple at Covington in June.

Rose beetles (*Macrodactylus subspinosus* Fabr.) were feeding on foliage and green apples at Silver Lake, June 13, on peaches, rose, cherry, plum, and grape at Terre Haute June 7, damaging apples at Plymouth June 25 and "by the

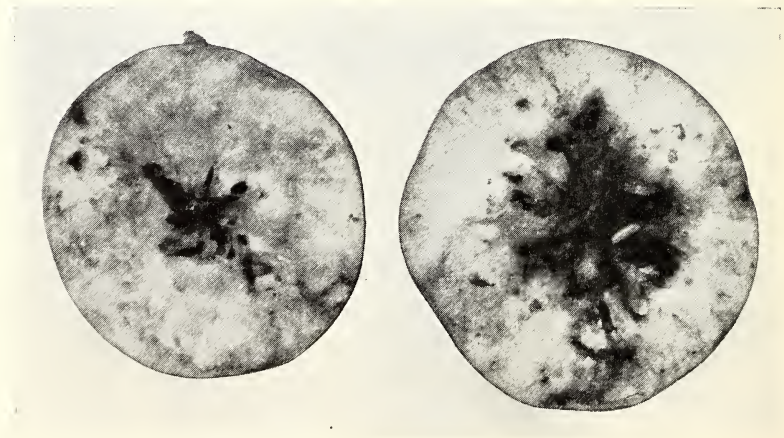


Fig. 2—Cross section of apple showing result of infestation by the apple maggot (*Rhagoletis pomonella* Walsh).

millions and eating everything" at Hobart, June 20. In one case injury to young chickens was reported.

Yellow-necked apple caterpillar (*Datana ministra* Drury) defoliated young apple trees at Morgantown August 6 and linden and apple trees at Lafayette, August 12.

Cherry slug (*Caliroa cerasi* L.) abundant on cherry at Indianapolis, August 13.

Black Cherry aphid (*Myzus cerasi* L.) abundant on cherry at Fremont.

Apple aphid (*Aphis pomi* DeG.) observed abundant on apple at Vincennes April 3. Noticed stem mothers giving birth to their first young at that time.

Catfacing (a trouble caused by the tarnished plant bug and probably other plant bugs) of peaches was considerably less than normal, according to Sazama, which may have been due to rainy weather at the time the insects are usually active.

It was generally abundant in many sections of the state. *Rhopalosiphum prunifoliae* Fitch and *Anuraphis roseus* Baker, were also moderately abundant in some areas.

Pear blister mite (*Eriophyes pyri* Pag.) was abundant at Mishawaka early in July.

The eight-spotted forester (*Alypia octomaculata* Fabr.) damaged grape at Crawfordsville early in July.

The current aphid (*Myzus ribis* L.) and the gooseberry aphid (*Aphis houghtonensis* Troop) were abunadnt at Sheridan the last of June. The gooseberry aphid (*Aphis houghtonensis* Troop) was also abundant at Marion and Berne in 1928 as evidenced by deformed shoots received in April.

Strawberry leaf-roller (*Ancylis comptana* Frohl.) was abundant at Lafayette in late June, at Mishawaka early in July and at Kokomo early in August.

Ips fasciatus Oliv. was reported injuring strawberries at Westville, July 26. Also reported from Kentland injuring tomatoes August 16. Probably not the primary injury in either case.

European red mite (*Paratetranychus pilosus* C. and F.) reported common at Orleans in November. R. A. Sazama reports it in increasing numbers at Vincennes.

Grape root worm (*Fidia viticida* Walsh) reported troublesome at Warsaw.

Grasshoppers injured young apple trees at Moorestown early in September by defoliating and girdling twigs.

Shade Tree and Shrub Insect

Bagworms (*Thyridopteryx ephemeraeformis* How.) were reported during late July and August from the following localities, Indianapolis, Brownsville, Terre Haute, Connersville, Winimac, Richmond, Knightstown and Cloverdale. Winimac is farther north than the usual range of this insect. Cedars were commonly attacked. In one instance rose was noticeably damaged and in another a three-year old apple orchard was badly defoliated.

Tussock moth caterpillars (*Hemerocampa leucostigma* S. and A.) was abundant on grape at Whitney and from Marion on shade trees the first half of July. They were common but not necessarily conspicuous in other central and southern Indiana localities.

Walnut caterpillar (*Datana intergerrima* G. and R.) abundant during July at Bloomfield and Lafayette.

Imperial moth caterpillar (*Basiloma imperialis* Drury) reported on maple at Greenfield, August 24.

Hickory horned devil (*Citheronia regalis* Fab.) was sent in from Commishey August 9 on sweet gum, Petersburg, August 24 on maple. It was sent in from a number of other localities during August but the host was not given. Apparently in no case was it sufficiently serious to call for control measures.

Catalpa sphinx caterpillar (*Ceratomia catalpae* Boisd.) was observed defoliating catalpa more or less generally throughout southern Indiana. In addition it was reported during August in abundance at Romney, Richmond and Lafayette. According to Sazama it was scarce in the vicinity of Vincennes.

Catalpa midge (*Itonida catalpae* Comst.) reported abundant and destructive at Edinburg (July 1), Elwood (July 6), and Huntington (Aug. 22).

Oyster shell scale (*Lepidosaphes ulmi* L.) generally abundant and destructive to ash, lilac and dogwood throughout the northern half of Indiana. Probably normally abundant.

Pine leaf scale (*Chionaspis pinifoliae* Fitch) normally abundant. Reported especially abundant on pines and spruce at Connersville in July.

Cottony maple scale (*Pulvinaria vitis* L.) normally abundant. Special reports of abundance were received during June, July and August from Tipton, New Richmond, Morocco, Anderson, Parker, Francisville, Plymouth, Garrett, Frankfort, Portland and Saratoga.

Tulip tree scale (*Toumeyella liriodendri* Gmel.) (fig. 3) abundant at Corydon, Darlington, Elberfeld and Henryville in late June and July.

Pine bark aphid (*Chermes pinicorticis* Fitch) was abundant on white pine at Rensselaer in October.

Fig. 3—Tulip tree scale *Toumeyella liriodendri* Gmel.), showing small, pale, elliptical young as well as the large, semi-spherical, brown mature individuals.

Maple aphids (*Periphyllus lyropicta* Kess.) were abundant on maples, especially Norway maple, at Pierceton, Edenburg, Morocco, Terre Haute, Salem, Portland, Fort Wayne, Woodburn and Lafayette during June and July

Maple Phenococcus (*Phenococcus acericola* King) was abundant on hard maple throughout central Indiana in late summer.

The native maple aphid (*Drepanaphis acerifoliae* Thos.) was abundant in southwestern Indiana and responsible for noticeable excretions of "honey dew."

The large willow aphid (*Melanoxantherium smithiae* Monl.) was abundant on willow at Crawfordsville and Anderson in August. While they were not noticeably harmful to the trees they were a considerable nuisance, especially because of the blood-red stain when crushed.

The linden lace bug (*Gargaphia tiliae* Walsh) (Drake det.) was observed abundant and destructive to lindens at Louisville, Ky., the last of July. Very likely this pest was similarly destructive across the river in Indiana.

The flat-headed borer (*Chrysobothris femorata* Fabr.) was destructive to maples at Freetown during August.

Lilac borer (?*Podosesia syringae* Harr.) reported damaging lilac at Salem, Crown Point and Evansville.

An unknown sawfly larva defoliated snowberry at Waveland during June.

Red spider (*Tetranychus telarius* L.) damaged evergreens, especially arbor vitae and cedar, at Connersville, Muncie, Scottsburg, Evansville, Anderson, Thorntown, Brownstown and Jasper. At Evansville, Norway spruce was badly infested.

The bladder maple gall (*Phyllocoptes quadripes* Shim.) was abundant on maple at Ray and Wolcottsville during June and July.

Flower Garden and Greenhouse Insects

Grasshoppers riddled flower garden plants at Michigan City in July.

Rose aphids reported during June and July from Newcastle, Gary and Pennville. The spiraea aphis (*Aphis spiraecola* Patch) and nasturtium aphid (*Aphis rumicis* L.) were generally abundant during June and July. The melon aphid (?*Aphis gossypii* Glov.) was abundant on catalpa and althea during June. The root aphid (*Prociphilus erigeronensis* Thos.) was abundant on aster at Richmond in June.

Rose leaf-hopper (*Empoa rosae* L.) damaged rose at Berne in June.

Cutworms damaged pansies in cold frames at Whitland in July.

Red spider (*Tetranychus telarius* L.) was abundant on phlox at Goldsmith June 3 and on evergreens at Carlisle June 6.

Eight-spotted forester (*Alypia octomaculata* Fabr.) defoliated ivy at Hammond in 1928 and the correspondent reports abundance of moths about the ivy vines June 18 of the present year.

Mealy bugs (*Pseudococcus citri* Risso) were abundant and destructive to coleus at Jeffersonville in August. Also mealy bugs (species?) were reported abundant on chrysanthemum, geranium and other plants in a greenhouse at Noblesville, August 15.

Cyclamen mite (*Tarsonemus pallidus* Banks) was very abundant on larkspur at Franklin, August 1.

Fungus gnat maggots (*Sciara sp.*) injured roots of potted plants at Albion in December.

Pests of Stored Products

Grain weevils were reported damaging wheat during September and October at Linnsburg, Lafayette, West Point, Ossian, and Williamsport.

Mediterranean flour moth (*Ephestia kuehniella* Zell.) was abundant in a mill at Pennville in August.

Bean Weevil (*Mylabris obtectus* Say) reported from Lafayette, Laconia, Benton, Gaston, and Franklin.

Household Insects

Fleas (*Ctenocephalus canis* Curt.) were outstanding pests throughout the year and many reports were received. The infestations included dwelling as well as barns and other farm buildings. The following localities reported serious infestations: Attica, Burrows, Crawfordsville, Flora, Greencastle, Hartford City, Indianapolis, Lafayette, Lebanon, Linton, Russellville, Salem, Shelbyville, South Bend and Tipton.

Bedbugs (*Cimex lectularius* L.) were reported abundant in homes during April at Indianapolis, Montezuma and Peru.

Clothes moths (*Tinea pellionella* L.) were destructive to over-stuffed furniture at Evansville, South Bend, Lafayette, Rockville, and Anderson.

Silver fish (*Lepisma saccharina* L.) were annoying in a home at Plymouth in August.

Ants (*Formicidae*) were annoying in homes throughout the summer at Atwood, Lafayette, Fort Wayne, Gary, Anderson and Martinsville. Ants were reported troublesome in the lawn at Indianapolis, Frankfort, Lafayette, Fort Wayne, Gary, Muncie and Winchester.

Carpet beetle (*Attagenus pecius* Oliv.) reported as destructive at Decatur, March 11.

Cigarette beetle (*Lasioderma serricorne* Fabr.) reported infesting over-stuffed furniture at Mt. Vernon.

Box-elder bugs were annoying in homes at Morocco and Collegeville, October 30 and November 7, respectively.

Miscellaneous Pests

Hog lice were reported from Lagro in August.

Termites (*Reticulitermes flavipes* Koll.) are destructive to buildings throughout the state and are the subject of inquiries throughout the year. Among the localities where serious damage has been reported are Bentonville, Columbus, Goshen, Indianapolis, Lafayette, South Bend, Tipton, Vincennes, Elkhart, Crawfordsville, Mulberry, Liberty, Tell City and Cynthiana. Termites were swarming at Lafayette, April 24.

Powder post beetles (*Lyctus* spp.) were reported attaching house timbers, including flooring and joists at Losantville, Knightstown, Russellville, Fort Wayne, Hope and Lafayette.

Chiggers (*Trombicula* sp.) were abundant generally and specifically in a lawn at Terre Haute in July.

Bee moth (*Galleria mellonella* L.) was abundant at Lafayette and Stinesville, attacking foulbrood infected colonies.

Kissing bugs (*Melanolestes picipes* H. S.) were reported April 10 from Freeborn, with the information that they were troublesome and that their "sting is worse than that of a wasp."

The following large caterpillars were sent in for identification: Io Caterpillar (*Automeris io* Fabr.) from Columbia City, September 20; saddleback caterpillar (*Sibine stimulae* Clem) on apple from Hagerstown, August 28; hickory horned devil (*Citheronia regalis* Fabr.) from Princeton and Delphi in September and Cecropia caterpillar (*Samia cecropia* L.) from Liberty, August 30.

THE DIGESTION OF A MOUSE BY A TARANTULA

John S. Andrews, Purdue University

In January 1928 a Central American tarantula came into my possession. During the two years that I have had it I have fed the tarantula a number of different animals. Among them have been cockroaches, wasps, bees, katy-dids, grasshoppers, flies, larvae of moths, and mice. These were placed in the cage alive and the spider was allowed to capture and kill them at its leisure. At times days passed before the spider would feed. At other times the prey would no more than touch the sand in the bottom of the cage when the tarantula would capture it and digest it.

On November 2, 1929 the tarantula was given a small mouse. The mouse was thrown so that the spider could easily grasp it. The mouse was held by the hind portion of the abdomen in such a position that the digestive fluids from the mouth and stomach might flow out upon the mouse. The mouse was very young and did not offer a great deal of resistance. It continued to move for twenty-five minutes or more and I do not believe that the tarantula used its poison on this victim. The mouse was fed at 3-45 P.M. and at 8:00 A.M. the next day the mouse had completely disappeared. I made a careful examination of the contents of the cage in order to discover any remains of the mouse that might be there. I found nothing save a piece of intestine about two inches long. There was no sign of hair, cartilage, bone or any other difficultly digestible substances.

On November 18, 1929 a second mouse was placed in the cage with the tarantula. This mouse was approximately three weeks old and very active. It ran about the cage quite oblivious to danger. For an hour the tarantula exhibited defensive reactions only. It never offered to strike and merely backed away whenever the mouse came near. Several times the tarantula allowed the mouse to crawl over it without any show of fight. During the next hour the action of the tarantula was more on the offensive. Twice it attempted to strike the mouse without success. The two had been placed in the cage at 2:00 P.M. and at 5:30 the tarantula had succeeded in striking the mouse. After the chelicerae had been inserted in the shoulder of the mouse, it was less than a minute before the mouse was dead. It ran about 12 inches and seemed to have great difficulty in moving its fore legs. It turned and fell over on its side, took two or three very deep breaths and died. The spider did not offer to eat this mouse and the latter was removed after four hours. This experiment was carried out in the photographic dark room as the tarantula is a nocturnal animal.

Since this experiment two other mice have been used without any positive results.

SOME STRUCTURAL PECULIARITIES OF STENOBOTHRIUM MACROBOTHRIUM, DIESING

Francis J. Wenninger, University of Notre Dame.

The species described in this paper has been known to science since the time of Diesing, in 1863, though no description of it has ever been published. Specimens are to be found in the Museums of Washington, Berlin and Vienna. About fourteen different hosts are reported. Of these the following are the more common: the Dolphin (Coryphaena hippuris), the Swordfish (Xiphias gladius), the Dusky Shark (Carcharius obscurus), the Tiger Shark (Galeocerdo tigrinus), the Artic Shark (Galeocerdo arcticus), and the Blue Shark (Caracharinus Milberti). The material at my disposal all came from the shark. The size of the specimens varies between 32 and 230 millimeters. The highest number of segments counted in any specimen was 140.

The head is several times as long as the remaining bothridial portion. The proboscides are poorly developed being thin, short, threadlike, only about a millimeter long, with uniform, widely separated hooks arranged in spirals, each spiral bearing about seven solid hooks. There is marked dorso-ventral differentiation. Individual segments are from 2.5 to 3 millimeters broad, while one of the last segments measured .025 millimeters in length.

The species is clearly protandrous, i.e., the male elements reaching maturity before those of the female. The primary end segment was missing in nearly all the specimens examined. A typical specimen having this end segment was found to have a total of 120 segments, and the uteri of the last 60 contained eggs. Portions of the strobila were found that contained no eggs at all. The explanation for this phenomenon was given by Van Beneden more than seventy years ago. The segments on stimulation by chemcial or mechanical means, or even on mere contact with water, burst and send out streams of eggs.

The cuticle is thick and covered with minute hairs visible only under the oil immersion lens. The muscular system has one specific characteristic. This is a strong muscular band that runs medially throughout the entire length of the individual both on the dorsal and on the ventral surfaces. This muscle is so compact that individual organs, as, for instance, the bladder, are diverted from their regular position and bent sideways. This muscle forms a longitudinal furrow that is visible along the whole length of the strobila and is the most conspicuous single characteristic of the species when viewed microscopically only.

The excretory system differs in several important details from that usually indicated in this genus. There is a branching from a main trunk which gives rise to numerous islands, and, secondly, there is a bladder in each segment. This branching is not to be understood as a mere splitting of the main trunk into smaller tubes and a further division of these into still smaller tubes till relatively minute capillaries are reached. It is rather an anastomosing of the smaller branches to meet again in a continuation of the same, the spaces between forming the island already mentioned. The bladder must be recognized as constituting a generic characteristic. There are on the dorsal surface of each segment several discharging vessels of the excretory system that lead through a very narrow dorso-ventrally situated passage into a bladder. In this species,

the bladder is evidently connected with a complicated network of canals of the system. The excretory pore may be seen in whole mounts. Here it appears as a diagonal split. Up to the present, this aperture has not been understood. There might be some difficulty in locating its position with certitude, as well as in distinguishing it from the openings of the uterus. However, the uterine openings in macrobothrium are rather high up in about the middle of the segment, while the excretory pore is very definitely situated in the posterior margin. The two points that need to be emphasized are the occurrence of this excretory pore in linear position on an apolytic chain of segments, and, secondly, its occurrence in the dorsal position.

A final characteristic of the species is that there are no preformed uterine openings. The uterus bursts in the same place in all the segments and pours out its contents. This fact is of prime systematic importance. The laceration for the aperture always occurs in the ventral median surface of the segment.

In conclusion, the following list of specific characters is offered for Stenobothrium macrobothrium.

1. An anaoplytic strobila with all segments even the last wider than long.
2. A muscular band running medially throughout the entire length of the individual on both dorsal and ventral surfaces.
3. A double layer of muscles at either end of each segment.
4. A many-branched excretory system whose branches meet again as continuations—the enclosed spaces forming island.
5. A complicated canal system of the excretory apparatus which discharges into a metameric bladder in each segment.
6. A marginal genital cloaca, situated anteriorly and ventrally.
7. A vagina opening beside the cirrus, under it and dorsal.
8. No preformed uterine openings.
9. Nucleoli in the larger germ cells.

RECORDS OF INDIANA DRAGONFLIES—IV. 1929

B. Elwood Montgomery, Purdue University

About 850 specimens of dragonflies, representing 72 species, were collected in Indiana during the season of 1929; most of these were collected by E. B. Williamson and others who accompanied him on collecting trips, including Eli Captain, Norman Shufelt, Lloyd A. Cowens, W. H. Ditzler, Z. E. Malcolm, H. T. Speith, A. D. Holloway, Paul Cook, C. H. Kennedy, and James G. Needham; John Warrick Emerson and V. R. Diamond each accompanied the writer on several collecting trips and made many captures.

New county records, notes on rare species, and such notes on habits and associations as seem new are recorded in this paper. A few earlier records omitted for various causes from previous papers in this series (Williamson, 1917, 1920; Montgomery, 1925, 1927, 1929) are included; such records have the year included —all records without indication of the year are from the 1929 season. Field notes are placed within quotation marks and are followed by initials "E. B. W." or "B. E. M.", indicating whether Mr. Williamson or the writer made the observations.

Two species not previously reported from the state are recorded, bringing the Indiana list of dragonflies to 131 species.

John Warrick Emerson and the writer visited the water supply reservoir at Oakland City, which was described last year (Montgomery, 1929) on July 28 and found the same species as were noted last year and in addition *Libellula pulchella*. On the same day a small pond in a meadow pasture along Indiana State Road 56 near the Pike-Dubois county line and a pond (Limeberry pond) covering about two acres, in Orange County, one-half mile south of the Paoli-Salem road, four and one-half miles from Paoli, were visited. The latter pond was surrounded for the most part with waste land covered with sparse vegetation, but merged into a woodland swamp at one end. The day was very warm—high temperature record for season—and Odonate life was very active; the usual Indiana pond association of Libellulines was noted but no Zygoptera were seen.

"Lotus Pond," Knox County, was visited on several different days but conditions were much changed from those in previous years (Montgomery, 1929). The water was very low, covering only the narrow open strip in the center of the pond; much of the area grown up with water smartweed and other plants was entirely dry. *Pachydiplax longipennis* and *Erythemis simplicicollis* were numerous but much reduced in numbers from last year. *Ischnura posita* was rare, *I. verticalis* common but not numerous, *Anomalagrion hastatum* was more common than at any time in past seasons; one male of *Nehalennia irene* and a male and a female of *Sympetrum vicinum* were taken. Hundreds of *Lestes rectangularis* were seen.

Extensive collecting was done in the Eel River basin in Cass County especially along Twelve Mile and Mud Creeks, parallel streams on the right bank of Eel River, west of Hoover. These creeks are fed by cold springs and there are marshes and swamps along their courses; their banks are partly wooded.

The numbers of Williamson's Indiana list (1917) are followed in this paper.

1. *Agrion aequabile* Say. **Cass Co.,** Mud Creek, June 23, a male was seen but not taken.

3. *Agrion maculatum* Beauvois. **Harrison Co.,** Indian Creek, Corydon, Aug. 31; **Jackson Co.,** Muscatatuck River, Sept. 1; **Wayne Co.,** Shaded Creek near Tuberculosis Sanitarium, July 28.

4. *Hetaerina americana* Fabricius. **Cass Co.,** Wabash River, west of Logansport, Sept. 15, Eel River near Hoover and Twelve Mile Creek, Sept. 22; **Harrison Co.,** Indian Creek, Corydon, Aug. 31.

5. *Hetaerina titia* Drury. **Harrison Co.,** Indian Creek, Corydon, Aug. 31; **Jackson Co.,** Muscatatuck River, Sept. 1. Collecting was done along the latter stream between a point one-half mile above the bridge on Indiana State Road 31 to a point about 150 yards below the nearby railroad bridge; *H. titia* was noted along this entire distance but *H. americana* was not seen.

9. *Lestes forcipatus* Rambur. **Huntington Co.,** pond at New Lancaster, Aug. 11; **Pike Co.,** pond in pasture, July 28.

11. *Lestes rectangularis* Say. **Cass Co.,** marsh along Twelve Mile Creek, July 14; **Huntington Co.,** upland pond near Salamonie River, June 9, ponds at Mt. Etna and New Lancaster, Aug. 11; **Pike Co.,** pond July 28, **Vigo Co.,** pond, three miles south of Pimento, July 4; **Wayne Co.,** July 28; **Wells Co.,** Vanemon Swamp, Sept. 14; a new late season record for this species in Indiana.

12. *Lestes uncatus* Kirby. **Cass Co.,** marsh along Twelve Mile Creek July 14.

13. *Lestes unguiculatus* Hagen. **Cass Co.,** Mud Creek, June 23 and Sept. 15, marsh along Twelve Mile Creek, July 14; **Huntington Co.,** ponds at Mt. Etna and New Lancaster, Aug. 11.

15. *Argia apicalis* Say. **Jackson Co.,** Muscatatuck River, Sept. 1; **White Co.,** Tippecanoe River below Schafer Lake, Sept. 8.

16. *Argia moesta* Hagen. **Cass Co.,** Wabash River, two to four miles west of Logansport, Sept. 15; **White Co.,** Tippecanoe River below Schafer Lake, Sept. 8.

17. *Argia sedula* Hagen. **White Co.,** Tippecanoe River below Schafer Lake, Sept. 8; one male was taken; associated with *A. moesta* which was common.

18. *Argia tibialis* Rambur. **Jackson Co.,** Muscatatuck River, Sept. 1. "About the only Argia here; *apicalis* rare and no other seen." (E. B. W.)

20. *Argia violacea* Hagen. **Pike Co.,** pond July 28; **Vigo Co.,** pond, Pimento, July 4.

21. *Enallagma antennatum* Say. **Pike Co.,** pond, July 28; **Vanderburg Co.,** pond, Mesker Park, Evansville, May 23, 1928.

25. *Enallagma civile* Hagen. **White Co.,** Tippecanoe River below Schafer Lake, Sept. 8.

28. *Enallagma ebrium* Hagen. **Huntington Co.,** pond at New Lancaster, July 21, "Only one was seen; it was doubtless a stray." (E. B. W.)

29. *Enallagma exsulans* Hagen. **Cass Co.,** Wabash River, Sept. 15; **White Co.,** Tippecanoe River below Schafer Lake, Sept. 8.

34. *Enallagma signatum* Hagen. **Huntington Co.,** pond at New Lancaster, Aug. 11; **Vanderburg Co.,** pond, Mesker Park, Evansville, May 23, 1928.

37. *Nehalennia irene* Hagen. **Cass Co.,** marsh near Twelve Mile Creek, July 14.

38. *Amphiagrion saucium* Burmeister. **Cass Co.,** Mud Creek, June 23.

39. *Chromagrin conditum* Hagen. **Cass Co.,** Mud Creek, June 23.

41. *Ischnura posita* Hagen. **Cass Co.,** Mud Creek, June 23, associated with the two preceeding species at a pool; **Jackson Co.,** Muscatatuck River,

Sept. 1; **Pike Co.**, pond, July 28; **White Co.**, Tippecanoe River below Schafer Lake, Sept. 8.

43. *Ischnura verticalis* Say. **Cass Co.**, Wabash River and Mud Creek, Sept. 15; **Jackson Co.**, Muscatatuck River, Sept. 1; **Pike Co.**, pond July 28; **Wayne Co.**, pond near Tuberculosis Sanitarium, July 28; **White Co.**, Tippecanoe River, below Schafer Lake, Sept. 8.

44. *Anomalagrion hastatum* Say. **Pike Co.**, pond, July 28.

45. *Tachopteryx thoreyi* Hagen. This rare species was taken at two localities, a female along Mud Creek, **Cass Co.**, June 23, and a total of eleven specimens, nine males and two females, at a bog along a creek below Monument City, **Huntington Co.**, June 9, 11, 30, July 10. "Rested on trees in every case," June 9. "Only one seen—flew in and alighted five feet high on large tree near creek in pasture," June 23. "Arrived at bog about noon and in 15 minutes E. B. W. caught three males and Eli Captain had two others in net but they escaped. Two or three more were seen in next 30 minutes when it grew very cloudy and no more seen. Saw no Cordulegaster to-day. Saw Tachopteryx capture moth; it flew adeptly, swiftly and relentlessly through low sedge growth and picked the moth up on the wing. Later another shot out over creek and seized a Calopteryx with all the rush and precision of an Accipiter; it then flew up 30 feet, alighting on trunk of a basswood—so far as I could tell it ate wings and all. (I believe Hagenius clips off Calopteryx wings)," June 30. "On tree as usual, and, as usual had to touch abdomen with net to cause it to raise abdomen above the bark. Saw only one other—a female—flew and alighted on my shoulder; as Eli approached with the net it flew away through the woods. I thought its abdomen was wet and a little muddy; I think it had been ovipositing. The season is over for Tachopteryx." July 10, (E. B. W.).

46. *Cordulegaster diastatops* Selys. **Cass Co.**, bog along Mud Creek, June 13 and 23; **Huntington Co.**, bog along creek near Monument City, June 9 and 11. This species, also rare in the state, was associated with the preceding species at the Huntington County bog, where a male was taken on each date noted; at Mud Creek this was more numerous than *T. thoreyi*—fourteen males were captured on June 23.

49. *Progromphus obscurus* Rambur. **Cass Co.**, Twelve Mile Creek, July 14.

50. *Hagenius brevistylus* Selys. **Cass Co.**, Eel River near Hoover, July 22, Aug. 11, Twelve Mile Creek, June 23, July 14 and 22, Mud Creek, June 23, "On Mud Creek saw a male (*H. brevistylus*) catch *Calopteryx maculata male*. Saw many floating wings of *C. maculata*. on Twelve Mile Creek." (See note under No. 45, *Tachopteryx thoreyi*, above) June 23, (E. B. W.).

51. *Ophiogomphus rupinsulensis* Walsh. **Cass Co.**, June 13; **Huntington Co.**, clearing in wood near Salamonie River, June 9.

53. *Gomphus crassus* Hagen. **Huntington Co.**, ripple in Salamonie River and clearing in wood near same stream, June 9.

54. *Gomphus lineatifrous* Calvert. (Listed as *G. dilatatus* Rambur in Indiana List, 1917; See Calvert, 1921). **Cass Co.**, near Mud Creek, June 13, Twelve Mile Creek, June 23, "On Twelve Mile today *G. lividus* was fairly common, *graslinellus* rare, *lineatrifrons* very rare (one seen), *H. brevistylus* fairly common but wary," June 23, (E. B. W.).

55a. *Gomphus externus* Hagen. **Gibson Co.**, Wabash River, July 27, 1927. This is the first Indiana record of this species which, however, has long been known to be regional for the state.

56. *Gomphus fraternus* Say. **Cass Co.,** Eel River, July 22.

58. *Gomphus graslinellus* Walsh. **Cass Co.,** Twelve Mile Creek, June 23, July 14, Eel River, July 22. "Two pairs seen in copulation—one on large flat rock in stream, other on ground near edge of water," July 14. "Only one taken—shot from thirty feet high in cottonwood. Frequently Gomphi were seen to fly over river and back to tree tops as this one did just before it was shot. Whether other individuals of this habit were same species was not determined," July 22, (E. B. W.).

59. *Gomphus lividus* Selys. **Cass Co.,** Twelve Mile Creek, June 23, Mud Creek, July 14.

59a. *Gomphus notatus* Rambur. **Clark Co.,** near Ohio River, Sept. 11, hanging on tree near pasture over which *Pantala flavescens* and *P. hymenaea* were flying in swarm; **Jackson Co.,** Muscatatuck River, Sept. 1, flying over ripple where *Dromogomphus spoliatus* and *Macromia taeniolata* were present; **Knox Co.,** orchard, near Wheatland, July 30, 1928.

60. *Gomphus quadricolor* Walsh. **Cass Co.,** near Mud Creek, June 13.

64. *Gomphus vastus* Walsh. **Cass Co.,** Eel River near Hoover, July 22.

65. *Gomphus ventricosus* Walsh. **Cass Co.,** near Mud Creek, June 13.

68. *Dromogomphus spinosus* Selys. **Cass Co.,** Eel River, July 22, Aug. 11, Mud Creek, June 23, Twelve Mile Creek, July 14, "Two or three were seen on stones and sand along creek. This one was taken on low broad leaf in marsh," July 14, (E. B. W.).

69. *Dromogomphus spoliatus*, Hagen. **Jackson Co.,** Muscatatuck River, Sept. 1.

70. *Boyeria vinosa* Say. **Cass Co.,** Mud Creek and Twelve Mile Creek, Sept. 22; **Harrison Co.,** Indian Creek, Corydon, Aug. 31; **Monroe Co.,** Salt Creek, Bloomington, Sept. 21. "Female was ovipositing in three inch log which was partly submerged. She was resting just above water line with abdomen extending into water and slightly curved around log toward under side so that eggs were being deposited in the log at a point well beneath the surface of the water;" Sept. 22, (B. E. M.). "After Shufelt struck at it with his net it flew in behind him and began laying eggs in his wet pants a few inches above the water," Aug. 31, (E. B. W.).

72. *Anax junius* Drury. **Cass Co.,** Mud Creek, Sept. 15, Twelve Mile Creek, Sept. 22; **Huntington Co.,** pond at New Lancaster. July 21 and Aug. 11, upland pond near Salamonie River, June 9.

75. *Aeshna constricta* Say. **Cass Co.,** marsh near Twelve Mile Creek, July 14.

78. *Aeshna umbrosa* Walker. **Cass Co.,** Wabash River, about five miles west of Logansport, and Mud Creek, Sept. 15, Twelve Mile Creek and Mud Creek, Sept. 22; **Wayne Co.,** shaded creek near Tuberculosis Sanitarium, July 28. Special attention was given to Aeshna collecting this year, but without very much success. Nine males of *A. constricta* (eight of them at Vanemon Swamp, **Wells Co.**), 12 males and three females of *A. umbrosa*, and one female of *A. verticalis* made up the entire catch. A large number of Aeshnines were present along Mud Creek, Sept. 15. After members of the collecting party had walked through a marsh area on a hillside near the creek the air seemed filled with a swarm of dragonflies which had been flushed. Of those collected 18 were *Anax junius*, three *Aeshna umbrosa* and one *A. verticalis*. One week later Mr. V. R. Diamond and the writer returned to this locality but saw no dragonflies; although

A. umbrosa was taken at a bog some distance up the creek and both *Anax junius* and *A. umbrosa* were taken at a marsh near Twelve Mile Creek. "Old Robinson Park Site, northeast of Fort Wayne, Allen County, Sept. 22. Examined old pond where one day years ago I got more than 40 Aeshnas; none there to-day. Only few *umbrosas* seen all day—no other Aeshnas." (E. B. W.).

79. *Aeshna verticalis* Hagen. See note under preceding species.

83. *Macromia illinoiensis* Walsh. **Cass Co.**, Eel River, near Hoover, July 22; **Harrison Co.**, Blue River, near Corydon, Aug. 31; **Lagrange Co.**, Pigeon River, near Howe, Aug. 7.

84. *Macromia pacifica* Hagen. **Cass Co.**, Eel River, near Hoover, Aug. 11.

85. *Macromia taeniolata* Rambur. **Jackson Co.**, Muscatatuck River, Sept. 1.

94. *Somatochlora linearis* Hagen. **Allen Co.**, creek in old Indian Reservation, southwest of Fort Wayne, July 18; one female, ovipositing in sand bar several inches above and several feet distance from water.

95. *Somatochlora tenebrosa* Say. **Huntington Co.**, bog near Monument City, July 10 and 21, a male and a female on the earlier date, a male on the latter. "Day bright, clear and windless, following rainy windy weather. Possibly half a dozen seen over bog, none at all on creek or along roads and paths; all erratic, often 30-40 feet high. Evidently the beginning of the season—both these very fresh. Male was beating an opening 30 feet in diameter, and flew 10-15 feet high, dropped down and hung like a Macromia on dead twig of willow, eight feet high. Female flew into bog and over it about 30 inches high, dropping down among brush in grass and sedges to oviposit in the cup-fulls of water exposed in tussocks of vegetation. Hovered just above water and thrust abdomen down at intervals, as near as I could see. It was in such spots that we had collected the three Somatochlora larvae on June 30," July 10. (E. B. W.)

99. *Libellula luctuosa* Burmeister. **Orange Co.**, Limeberry pond, July 28; **Wayne Co.**, pond near Tuberculosis Sanitarium, July 28.

100. *Libellula pulchella* Drury. **Cass Co.**, Eel River near Hoover, July 22, bog along Mud Creek, June 23; **Orange Co.**, Limeberry pond, July 28.

102. *Libellula semifasciata* Burmeister. **Cass Co.**, bog along Mud Creek, June 23.

103. *Libellula vibrans* Fabricius. **Huntington Co.**, pond at New Lancaster, July 21.

104. *Plathemis lydia* Drury. **Cass Co.**, Twelve Mile Creek, Sept. 22; **Orange Co.**, Limeberry pond, July 28; **Pike Co.**, pond in pasture, July 28.

105. *Perithemis tenera* Say. **Harrison Co.**, ferry over Ohio River south of Corydon, Aug. 31—a female flew across river, falling into water near Kentucky shore and was picked up; **Pike** Co., pond, July 28.

106a. *Erythrodiplax minuscula* Rambur. **Vigo Co.**, pond three miles south of Pimento, July 15, 1928, one female. This appears to be the first definite record in the Ohio valley of this species which has been carried on various central states lists from Hagen's statement (1861), "Hab. Kentucky."

107. *Erythemis simplicicollis* Say. **Clark Co.**, Ohio River at Jeffersonville, Sept. 11; **Orange Co.**, Limeberry pond, July 28; **Pike Co.**, pond, July 28.

111. *Sympetrum obtrusum* Hagen. **Cass Co.**, Mud Creek Sept. 15, Twelve Mile Creek, Sept. 22.

112. *Sympetrum rubicundulum* Say. **Cass Co.**, Mud Creek, Sept. 15, Twelve Mile Creek, July 14 and Sept. 22; **White Co.**, Tippecanoe River below Schafer Lake, Sept. 8.

114. *Sympetrum vicinum* Hagen. **Cass Co.,** Mud Creek, Sept. 22; **Harrsion Co.,** near Blue River at Corydon, Aug. 31; **White Co.,** Tippecanoe River below Schafer Lake Sept. 8; **Wells Co.,** alive in gutter, Bluffton, Nov. 13, 1914—this late capture not previously recorded extends the season for the species in Indiana almost a month.

115. *Pachydiplax longipennis* Burmeister. **Pike Co.,** pond, July 28; **Vigo Co.,** pond at Pimento; **Wayne Co.,** pond near Tuberculosis Sanitarium, July 28.

117. *Leucorhinia intacta* Hagen. **Huntington Co.,** upland pond near Salamonie River, June 9.

118. *Celithemis elisa* Hagen. **Huntington Co.,** pond at New Lancaster, Aug. 11; **Orange Co.,** Limeberry pond, July, 28.

121. *Pantala flavescens,* Fabricius. **Clark Co.,** along Ohio River at Jeffersonville, Sept. 11; **Huntington Co.,** pond at New Lancaster, Aug. 11; **Orange Co.,** Limeberry pond, July 28. At a pumping station near Bluffton Eli Captain saw females of this species ovipositing in an oil pool; it was not determined if such females survive but one was seen to oviposit more than once.

122. *Pantala hymenaea* Say. **Clark Co.,** near Ohio River at Jeffersonville, Sept. 11. Four specimens of this species and one of *P. flavescens* were taken by H. Spieth who made this observation, "Insects flying in swarm about 100 feet from river in an old deserted, uncultivated, overgrown pasture which, in the spring, is very swampy."

132. *Tramea carolina* Linne. **Huntington Co.,** wood clearing near Salamonie River, June 9.

124. *Tramea lacerata* Hagen. **Huntington Co.,** upland pond near Salamonie River, June 9, pond at New Lancaster, July 21; **Orange Co.,** Limeberry pond, July 28; **Vigo Co.,** pond three miles south of Pimento, July 4; **Wayne Co.,** pond near Tubersulosis Sanitarium, July 28. "Several seen; pair ovipositing, male in usual attendance part of time, female alone and more industrious part of time," July 29, (E. B. W.).

125. *Tramea onusta* Hagen. **Orange Co.,** Limeberry pond, July 28; **Vigo Co.,** pond at Pimento, July 4.

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Heck, Joseph E., Connersville....M26
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Helman, Howard H., North Manchester....M27
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*Hess, Walter N., Clinton, New York....M17, F23
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Holl, Dr. Carl Waldo, North Manchester....M26
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Howick, Howard, Ball Teachers College, Muncie....M21

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Hunt, Herschel, Hazelton....M28
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Hyatt, George F., R. R. 2, Versailles....M25
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Inskeep, Anna M., Monticello....M24
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*Kern, Frank D., State College, Pa....M05, F12
Kiesling, Norman, R. R. 10, Logansport....M28

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Kintner, Kenneth E., 1004 East St., North Manchester.....M29
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Lefler, Glenn Q., Warren.....M28
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Marting, Dorsey P., Eckerty....M26

Malek, George, Gardner, Ill.....M27
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Michael, Curtis B., Windsor, Illinois.....M26
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Miner, Wallace B., Laketon.....M28
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Orahood, Harold, Union Mills....M14
Organ, James F., R. R. 1, Vincennes....M29
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Pittenger, Samuel Arthur, Selma.....M26
Pittenger, John S., 802 East Third St., Bloomington.....M26
Pittman, Lenard E., Fairbanks.....M26
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Railsback, O. L., Teachers College, Charleston, Illinois.....M24
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Rauth, Adolph W., Commonwealth Power Co., Jackson, Mich.....M25

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